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Manual on

Uniform Traffic Control Devices for Streets and Highways

Prepared by a joint committee of

American Association of State Highway Officials

Institute of Traffic Engineers

National Conference on Street and Highway Safety

PUBLIC ROADS ADMINISTRATION

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CONTENTS

	Page
Introduction.....	1
Use and misuse of traffic control devices.....	2
Responsibility for selection and installation.....	3
Definitions.....	3
Relating to the highway.....	3
Relating to traffic.....	4
Relating to signs.....	4
Relating to markings.....	4
Relating to signals.....	5
Relating to islands.....	5

Part I—SIGNS

A—Introduction

Section 1. Function of signs.....	7
Section 2. Legal authority.....	7
Section 3. Classification of signs.....	8
Section 4. Excessive use of signs.....	8
Section 5. Standardization of signs.....	8
Section 6. Standardization of design.....	8
Section 7. Sign shapes.....	8
Section 8. Colors.....	9
Section 9. Dimensions.....	9
Section 10. Symbols.....	10
Section 11. Word messages.....	10
Section 12. Lettering.....	10
Section 13. Illumination and reflectorization.....	10
Section 14. Means of illumination.....	10
Section 15. Means of reflectorization.....	11
Section 16. Sign borders.....	12
Section 17. Standardization of position.....	12
Section 18. Standardization of application.....	13
Section 19. Erection.....	13
Section 20. Materials.....	16
Section 21. Sign posts and their foundations.....	16
Section 22. Maintenance.....	16
Section 23. Reflector markers.....	17
Section 24. Major routes.....	17

B—Regulatory Signs

Section 25. Application of regulatory signs.....	17
Section 26. Classification of regulatory signs.....	18
Section 27. Design of regulatory signs.....	18
Section 28. Stop sign.....	18
Section 29. Design of Stop sign.....	18
Section 30. Warrants for Stop sign.....	19
Section 31. Location of Stop sign.....	20
Section 32. Speed Limit sign.....	22
Section 33. Location of Speed Limit sign.....	22
Section 34. Night Speed sign.....	23
Section 35. Speed Zone Ahead sign.....	24
Section 36. End (35) Mile Speed sign.....	24
Section 37. Turn Prohibition signs.....	24
Section 38. Traffic Signal Speed sign.....	25
Section 39. No Passing sign.....	25
Section 40. End No Passing Zone sign.....	26
Section 41. Keep Right Except to Pass sign.....	26
Section 42. Keep Right sign.....	26
Section 43. Do Not Enter sign.....	27
Section 44. Selective exclusion signs.....	27
Section 45. One Way sign.....	28

	Page
Section 46. Two Way Traffic Ahead sign	30
Section 47. Parking and stopping signs	30
Section 48. Placement of parking signs	31
Section 49. Parking signs in rural districts	32
Section 50. Walk on Left sign	32
Section 51. Pedestrian Crossing signs	33
Section 52. Pedestrian-Actuated Signal sign	33
Section 53. Road Closed sign	33
Section 54. Load Limit sign	34
Section 55. Other regulatory signs	35

C—Warning Signs

Section 56. Application of warning signs	35
Section 57. Design of warning signs	38
Section 58. Location of warning signs	38
Section 59. Turn sign	39
Section 60. Curve sign	39
Section 61. Reverse Turn sign	39
Section 62. Reverse Curve sign	40
Section 63. Winding Road sign	41
Section 64. Cross Road sign	41
Section 65. Side Road sign	42
Section 66. T Symbol sign	42
Section 67. Y Symbol sign	43
Section 68. Large Arrow sign	43
Section 69. Stop Ahead sign	44
Section 70. Signals Ahead sign	44
Section 71. Hill sign	44
Section 72. Bump sign	45
Section 73. Dip sign	45
Section 74. Narrow Road sign	46
Section 75. Pavement Narrows sign	46
Section 76. Divided Highway Ahead sign	46
Section 77. Divided Highway Ends sign	47
Section 78. Narrow Bridge sign	47
Section 79. One Lane Bridge sign	47
Section 80. Low Clearance sign	48
Section 81. Pavement Ends sign	48
Section 82. Men Working sign	48
Section 83. Fresh Oil sign	49
Section 84. Soft Shoulders sign	49
Section 85. Slippery When Wet sign	50
Section 86. Double Arrow sign	50
Section 87. School sign	50
Section 88. Railroad Advance Warning sign	51
Section 89. Railroad Crossbuck sign	52
Section 90. Crossing signs	52
Section 91. Advisory Speed sign	53
Section 92. Other warning signs	53

D—Guide Signs

Section 93. Application of guide signs	53
Section 94. Design of guide signs	54
Section 95. Route markers and auxiliary markers	54
Section 96. Design of Route Markers	54
Section 97. Oversize Route Markers	55
Section 98. Confirming and Reassurance Markers	55
Section 99. Junction sign	57
Section 100. Oversize Junction sign	58
Section 101. Combination Junction sign	60
Section 102. Advance Turn Marker	60
Section 103. Oversize Turn Marker	63
Section 104. Directional Marker	63
Section 105. Location of directional marking assemblies	65
Section 106. Oversize Directional Marker	66
Section 107. Temporary Marker	66
Section 108. Alternate Marker	66

	Page
Section 109. By-pass Marker.....	67
Section 110. Business Route Marker.....	67
Section 111. Detour Marker.....	67
Section 112. Cardinal Direction Marker.....	68
Section 113. Destination sign.....	68
Section 114. Location of Destination signs.....	70
Section 115. Distance sign.....	71
Section 116. Street Name sign.....	72
Section 117. Information signs.....	72

Part II—MARKINGS

A—Introduction

Section 118. Functions and limitations of markings.....	75
Section 119. Legal authority.....	75
Section 120. Standardization.....	75
Section 121. Types of markings.....	75
Section 122. Materials.....	76
Section 123. Colors.....	77
Section 124. Types of striping.....	78
Section 125. Width of lines.....	79
Section 126. ReflectORIZATION.....	79
Section 127. Maintenance.....	79

B—Pavement and Curb Markings

Section 128. Center lines.....	79
Section 129. Center lines on rural roads.....	80
Section 130. Center lines on urban streets.....	81
Section 131. Lane lines.....	81
Section 132. Lane lines on rural roads.....	81
Section 133. Lane lines on urban streets.....	81
Section 134. No-passing zones.....	82
Section 135. No-passing zones on two- and three-lane roadways.....	82
Section 136. Warrants for no-passing zones.....	84
Section 137. Pavement edges.....	86
Section 138. Pavement-width transitions.....	86
Section 139. Approach to an obstruction.....	86
Section 140. Streetcar clearance lines.....	88
Section 141. Turn markings.....	88
Section 142. Transverse lines.....	91
Section 143. Stop lines.....	91
Section 144. Cross-walk lines.....	91
Section 145. Route directions.....	93
Section 146. Approach to railroad crossing.....	93
Section 147. Parking space limits.....	93
Section 148. Word markings.....	95
Section 149. Curb markings for parking restrictions.....	95

C—Object Markings

Section 150. Application of object markings.....	95
Section 151. Objects within the roadway.....	97
Section 152. Lighting or reflectORIZATION of obstructions.....	97
Section 153. Object markings on curbs.....	99
Section 154. Objects adjacent to the roadway.....	99

D—Reflector Markers

Section 155. Application of reflector markers.....	99
Section 156. Hazard markers.....	99
Section 157. Delineators.....	100

Part III—SIGNALS

A—Introduction

Section 158. Definitions.....	103
Section 159. Value of signals.....	103
Section 160. Standardization.....	104
Section 161. Legal authority.....	104
Section 162. Classification.....	105

B—Features Common to Fixed-Time and Traffic-Actuated Signals

	Page
Section 163. General aspects of signals.....	105
Section 164. Design for future needs.....	105
Section 165. Number of lenses per signal face.....	105
Section 166. Color and position of lenses.....	106
Section 167. Meaning of color and arrow indications.....	106
Green, yellow, and red (alone).....	107
Red with green arrow.....	107
Flashing red and yellow.....	108
Section 168. Shapes and dimensions of lenses.....	108
Section 169. Lettering on lenses.....	109
Section 170. Illumination of lens.....	109
Section 171. Visibility and shielding of lens.....	110
Section 172. Auxiliary illuminated signs.....	110
Section 173. Number of signal faces.....	110
Section 174. Limit of signal-controlled area.....	111
Section 175. Location of signal faces at intersections.....	111
Section 176. Height of signal faces.....	113
Section 177. Pointing of signal faces.....	113
Section 178. Location in relation to curb line.....	114
Section 179. Location in relation to the pavement or traveled surface.....	114
Section 180. Removal of confusing advertising lights.....	114
Section 181. Provision for future installation.....	114
Section 182. Types of mounting for signal heads.....	115
Section 183. Installation of underground conduit or cable.....	115
Section 184. Selection of cable.....	116
Section 185. Insulation of cable.....	116
Section 186. Cable positions and clearances.....	116
Section 187. Messenger wires.....	117
Section 188. Efficiency and continuity of operation.....	117
Section 189. Length of cycle.....	117
Section 190. Number of traffic phases.....	118
Section 191. Rotation of intervals.....	118
Section 192. Traffic movement intervals proportioned to traffic requirements.....	119
Section 193. Unexpected conflicts during Go interval.....	119
Section 194. Vehicle-clearance interval.....	120
Section 195. Adequacy of maintenance.....	120
Section 196. Signal lamp replacement.....	120
Section 197. Cleaning.....	121
Section 198. Maintenance of controllers.....	121
Section 199. Painting.....	121
Section 200. Maintenance records.....	122

C—Comparison of Fixed-Time and Traffic-Actuated Control

Section 201. Relative adaptability to normal intersection requirements.....	122
Section 202. Special merits of fixed-time control.....	123
Section 203. Special merits of traffic-actuated control.....	123
Section 204. Other factors governing selection of type of control.....	124

D—Fixed-Time Signals

Section 205. Definition.....	125
Section 206. Advance engineering data required.....	125
Section 207. Warrants for fixed-time signals.....	125
Section 208. Minimum vehicular volume.....	127
Section 209. Interruption of continuous traffic.....	129
Section 210. Minimum pedestrian volume.....	130
Section 211. Coordinated movement.....	131
Section 212. Accident hazard.....	132
Section 213. Combination of warrants—other factors.....	133
Section 214. Selection of type of fixed-time control mechanism.....	133
Section 215. Nonsynchronous fixed-time controller for isolated inter- sections.....	134
Section 216. Program type of fixed-time controller for isolated inter- sections.....	134
Section 217. Synchronous type of fixed-time controller for isolated inter- sections.....	134
Section 218. Controllers providing for coordination.....	134

	Page
Section 219. Signal timing in accordance with traffic requirements.....	135
Section 220. Division of total cycle time.....	135
Section 221. Coordination of fixed-time signals.....	136
Section 222. Types and selection of coordination.....	137
Section 223. Simultaneous system.....	137
Section 224. Alternate system.....	137
Section 225. Simple progressive system.....	138
Section 226. Flexible progressive system.....	138
Section 227. Conditions affecting efficiency of signal systems.....	139
Section 228. Manual control.....	140
Section 229. Speeds for progressive systems.....	140
Section 230. Signs indicating timed speed.....	140
Section 231. Coordination with railroad crossing signals.....	140
Section 232. Rate of flashing.....	141

E—Traffic-Actuated Signals

Section 233. Definition.....	141
Section 234. Warrants for intersection control.....	141
Section 235. Warrants for nonintersection control.....	142
Section 236. Types of traffic-actuated control, and factors governing selection.....	142
Section 237. Semi-traffic-actuated control.....	143
Section 238. Full traffic-actuated control.....	143
Section 239. Coordinated control.....	144
Section 240. Pedestrian-actuated control.....	144
Section 241. Speed control.....	145
Section 242. One-way restricted zone control.....	146
Section 243. Detectors and controllers.....	147
Section 244. Types of detectors.....	147
Section 245. Pressure-sensitive detectors.....	147
Section 246. Magnetic detectors.....	147
Section 247. Sound-sensitive detectors.....	148
Section 248. Light-sensitive detectors.....	148
Section 249. Pedestrian push-button detectors.....	148
Section 250. Types of controllers.....	148
Section 251. Two-movement, semi-traffic-actuated controller with time extension.....	149
Section 252. Two or more movements, full or semi-traffic-actuated controller with time extension.....	149
Section 253. Traffic-actuated speed control for nonintersection locations.....	149
Section 254. Two-movement, full or semi-traffic-actuated controller with speed control.....	149
Section 255. Two-movement, full traffic-actuated controller with automatic adjustments of periods with respect to traffic volume, relative density, and elapsed time.....	150
Section 256. Two-phase, full traffic-actuated control for one-way restricted zone.....	150
Section 257. Additional flexibility for controllers used in coordinated systems.....	150
Section 258. Provision for manual operation.....	150
Section 259. Installation of traffic-actuated signals.....	150
Section 260. Distance of vehicle detectors from Stop line.....	151
Section 261. Location of vehicle detectors from center line.....	152
Section 262. Installation of pedestrian detectors.....	153
Section 263. Installation of streetcar detectors.....	153
Section 264. Operation and adjustment of traffic-actuated signals.....	154
Section 265. Continuous operation.....	154
Section 266. Time intervals and adjustments.....	154
Section 267. Interval sequence.....	156
Section 268. Rotation of phases.....	156

F—Special Pedestrian Signals

Section 269. Definition.....	157
Section 270. Warrants.....	157
Section 271. Type of control.....	158
Section 272. General design requirements.....	158
Section 273. Meaning of indications.....	159

Section 274. Location.....	160
Section 275. Operation.....	160
Section 276. Phases and intervals.....	160

G—Other Special Traffic Signals

Section 277. Types of special traffic signals.....	161
Flashing beacons and signals:	
Section 278. Definition and application.....	161
Section 279. Warrants.....	161
Section 280. Types of control.....	162
Section 281. Design.....	162
Section 282. Location.....	162
Section 283. Operation.....	163
Lane-direction traffic signals:	
Section 284. Definition and application.....	163
Section 285. Warrants.....	163
Section 286. Types of control.....	163
Section 287. Design.....	164
Section 288. Location.....	164
Section 289. Operation.....	164
Traffic signals at drawbridges:	
Section 290. Application.....	164
Section 291. Warrants.....	164
Section 292. Design.....	164
Section 293. Location.....	165
Section 294. Operation.....	165

H—Train-Approach Signals and Gates

Section 295. Railroad grade-crossing protection.....	165
Train-approach signals:	
Section 296. Classification and definitions.....	165
Section 297. Warrants.....	166
Section 298. Types of control.....	166
Section 299. Design.....	166
Section 300. Location.....	166
Section 301. Installation.....	166
Section 302. Operation.....	167
Section 303. Maintenance.....	167
Railroad-highway grade-crossing automatic gates:	
Section 304. Application.....	167
Section 305. Warrants.....	167
Section 306. Types of control.....	168
Section 307. Design.....	168
Section 308. Location.....	168
Section 309. Installation.....	168
Section 310. Operation.....	168
Section 311. Maintenance.....	169

Part IV—ISLANDS

A—Introduction

Section 312. Function of islands.....	171
Section 313. General engineering requirements.....	171
Section 314. Classification.....	172
Section 315. Standardization.....	174

B—Loading Islands

Section 316. Legal authority.....	174
Section 317. Functions.....	174
Section 318. Warrants.....	174
Section 319. Location.....	175
Section 320. Access.....	175
Section 321. Elements of design.....	175
Section 322. Designation of area.....	176
Section 323. Dimensions.....	177
Section 324. End protection.....	178

	Page
Section 325. Approach-end treatment.....	180
Section 326. Side protection.....	180
Section 327. Illumination and reflectorization.....	181
Section 328. Direction of flow.....	182
Section 329. Signs.....	182
Section 330. Markings.....	182
<i>Summary specifications for loading islands.....</i>	<i>183</i>
C—Refuge Islands	
Section 331. Legal authority.....	183
Section 332. Functions.....	183
Section 333. Warrants.....	183
Section 334. Location.....	185
Section 335. Elements of design.....	185
Section 336. Designation of area.....	185
Section 337. Continuous median strip.....	185
Section 338. Dimensions.....	185
Section 339. End protection.....	188
Section 340. Approach-end treatment.....	188
Section 341. Side protection.....	188
Section 342. Illumination and reflectorization.....	188
Section 343. Signs.....	188
Section 344. Markings.....	188
<i>Summary specifications for refuge islands.....</i>	<i>189</i>
D—Divisional Islands	
Section 345. Legal authority.....	189
Section 346. Functions.....	189
Section 347. Warrants.....	190
Section 348. Elements of design.....	191
Section 349. Designation of area.....	191
Section 350. Dimensions.....	192
Section 351. Curbs.....	194
Section 352. Approach-end treatment.....	195
Section 353. Illumination and reflectorization.....	196
Section 354. Signs.....	197
Section 355. Markings.....	197
<i>Summary specifications for divisional islands.....</i>	<i>197</i>
E—Channelizing Islands	
Section 356. Legal authority.....	197
Section 357. Functions.....	197
Section 358. Warrants.....	198
Section 359. Elements of design.....	198
Section 360. Designation of area.....	198
Section 361. Dimensions.....	201
Section 362. Curbs.....	202
Section 363. Approach-end treatment.....	202
Section 364. Illumination and reflectorization.....	202
Section 365. Signs.....	202
Section 366. Markings.....	203
<i>Summary specifications for channelizing islands.....</i>	<i>203</i>

Appendix A

Glossary of traffic signal terms.....	205
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Appendix B

Specifications for materials and manufacture.....	209
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INDEX

Index.....	215
------------	-----

ILLUSTRATIONS

	Page
Figure 1.—Height and lateral location of signs—typical installations.....	14
Figure 2.—Height and lateral location of signs—typical installations.....	15
Figure 3.—Typical locations for Stop signs.....	21
Figure 4.—Location of One Way signs.....	29
Figure 5.—Typical applications of warning signs.....	36
Figure 6.—Typical applications of warning signs.....	37
Figure 7.—Method for determining degree of curvature and central angle of horizontal curves.....	40
Figure 8.—Typical route markings at intersections (for one direction of travel only).....	56
Figure 9.—Typical route markings at intersections (for one direction of travel only).....	59
Figure 10.—Typical route markings at intersections (for one direction of travel only).....	62
Figure 11.—Typical information signs, selected from State highway department manuals.....	73
Figure 12.—Standard pavement markings for no-passing zones.....	83
Figure 13.—Method of locating and determining the length of no-passing zones on vertical and horizontal curves.....	85
Figure 14.—Typical pavement-width transition markings.....	87
Figure 15.—Approach markings for obstructions in the roadway.....	89
Figure 16.—Typical designs for turn markings on pavements.....	90
Figure 17.—Typical urban pavement markings, showing center lines, lane lines, Stop lines, cross-walk lines, parking-space limits, and route markings.....	92
Figure 18.—Standard pavement markings at railroad crossings.....	94
Figure 19.—Method of developing elongated letters for pavement markings.....	96
Figure 20.—Typical markings on objects in and adjacent to the roadway.....	98
Figure 21.—Arrow lens design; Institute of Traffic Engineers.....	109
Figure 22.—Standards for traffic signal locations.....	112
Figure 23.—Typical condition diagram.....	126
Figure 24.—Typical collision diagram.....	126
Figure 25.—WALK lens design; Institute of Traffic Engineers. A typical WAIT lens design.....	159
Figure 26.—WALK-WAIT signal installation.....	160
Figure 27.—A raised loading island with illuminated metal grill buffer and approach-end pavement marking.....	172
Figure 28.—A refuge island with low marker lights, arrow, and sign. Pedestrians can cross the street without stepping up on this island.....	172
Figure 29.—A divisional island extending from a bridge pier. The approach end is signed, striped, and reflectorized.....	173
Figure 30.—Channelizing islands at an intersection, with supplementary signs and pavement markings. Concrete curbs delineate the island edges.....	173
Figure 31.—A raised loading island in a business district, with metal grill platform protected by side rail and metal splash plate. The steel buffer and pylon are striped and illuminated.....	175
Figure 32.—A raised loading island with highly effective approach-end treatment of pavement marking, painted curb, sign, reflector cluster, and low marker lights. This island has no buffer.....	176
Figure 33.—Posts and chains provide side protection for this raised loading island. The rounded buffer is striped and illuminated for high visibility.....	177
Figure 34.—End protection for this loading island is furnished by heavy metal posts, the center one low enough to allow clear view of the reflectorized cluster. Side protection is provided by posts and chains, set back from the curb. The clean-cut openness of this island permits good visibility.....	177
Figure 35.—A street-level loading island in a business district. The loading area is protected by metal posts with a sheet-metal splash plate, and the pylon is striped and illuminated for high visibility.....	178

	Page
Figure 36.—A concrete loading island with end protection provided by a rounded concrete buffer. Two alternately flashing lights and an illuminated striped panel warn drivers of approaching vehicles of the island's presence.....	179
Figure 37.—A raised loading island with protection provided by an illuminated and reflectorized buffer with long sloping prow.....	179
Figure 38.—Side protection for this loading island is provided by a concrete panel. The high, massive buffer is a sight obstruction, and equal utility and better appearance could have been obtained by a more open design....	180
Figure 39.—Approach-end treatment to give advance warning of the presence of this loading island consists of high and low reflector clusters, yellow-painted curb, and mushroom button.....	181
Figure 40.—A raised refuge island with buffer and curb striped for high visibility.....	184
Figure 41.—An elaborate refuge island with special high-visibility treatment. The cross walk is cut through at pavement level, and pedestrians are well protected from both through and turning vehicles.....	184
Figure 42.—Combination channelizing and refuge islands with marker lights. The center islands extend into but not entirely across the cross walks.....	186
Figure 43.—A combination channelizing and refuge island, with protection from approaching traffic provided by the illuminated buffer and prow at the left. The small buffer at the right provides protection from turning vehicles and serves as a base for the traffic signal.....	186
Figure 44.—Combination divisional, channelizing, and refuge islands with desirable tapered shape, curb-level marking lights, and overhead illumination.....	187
Figure 45.—Channelizing islands and pavement markings at a complicated intersection. The raised islands also serve as refuge islands.....	187
Figure 46.—A paved median in a suburban area. The width of the second island is reduced by combined acceleration and deceleration lanes provided for vehicles making left turns to and from the divided street.....	190
Figure 47.—Separate lanes for left turns are notched into this wide median. The roadway is illuminated, and traffic signals control movements at the intersection.....	191
Figure 48.—Introduction of a divisional island in the vicinity of a hill should be well in advance of the crest. Appropriate pavement marking further reduces the hazard.....	192
Figure 49.—At this channelized Y intersection, with irregular-shaped islands, traffic signals regulate the principal crossing movement.....	193
Figure 50.—Approach-end treatment for this median includes jiggle bars, sign, reflector cluster, reflecting curb, and pavement marking. The median is widened for an acceleration lane and for protection of crossing vehicles. The jiggle bars shown here were made of asphaltic mix, placed directly on the concrete and painted white.....	195
Figure 51.—Separation to permit the addition of central islands was an important factor in the channelization of this intersection. High-visibility curbs were used and an overhead traffic signal regulates the principal crossing movement.....	199
Figure 52.—This channelized T intersection has stop control for crossing movements. The near island is delineated by jiggle bars and painted stripes.....	199
Figure 53.—Channelizing islands of various sizes and shapes are used at the terminals of highway grade separation ramps.....	200
Figure 54.—Painted stripes and stanchions designate this island area from which motor vehicles are excluded.....	200
Figure 55.—These ramp terminals are outlined by guard posts along the shoulders. A low, rounded divisional island along the main highway discourages improper left turns.....	201
Figure 56.—Advantage is taken of curvature in this approach-end treatment consisting of a contrasting pavement wedge leading to the curbed island nose. The overhead signs are illuminated.....	202
Figure 57.—This approach-end treatment has a slightly raised, roughened tongue in advance of a double curb with inset reflectors. The signs are an experimental installation	203

INTRODUCTION

Uniformity in traffic laws and regulations was emphatically urged by the President's Highway Safety Conference held in Washington May 8-10, 1946, and is widely recognized as one of the most important objectives in the program to reduce accidents and facilitate the orderly flow of traffic. This *Manual on Uniform Traffic Control Devices for Streets and Highways* is an essential part of this uniformity plan, and its adoption was specifically recommended by the President's Conference.

Approved legislative standards for States and cities are available in Act V of the Uniform Vehicle Code—the *Uniform Act Regulating Traffic on Highways*—and in the *Model Traffic Ordinance*,¹ respectively. Both the Code and the Ordinance require the placing of signs or other traffic control devices to make some of their provisions effective, and both define the legal meaning of certain devices. The Code directs the State authorities to adopt a manual for a uniform system of traffic control devices, and the Ordinance requires devices under municipal jurisdiction to conform thereto.

The Federal-aid Highway Act of 1944 also recognizes the need for approved standards for traffic control devices, and as to highways receiving Federal aid authorizes the Commissioner of Public Roads to require that the devices conform to such standards.

Inasmuch as application of many parts of the manual involves engineering analyses, the counsel of traffic engineers is highly desirable in its use. If such counsel is not available, however, careful attention to the manual recommendations will make it possible to avoid many errors and pitfalls.

This edition of the manual supersedes all previous editions, including the original edition printed in 1935 and reprinted in 1937, mimeographed revisions made in 1939, and the War Emergency Edition issued in 1942. The Joint Committee on Uniform Traffic Control Devices, which has prepared the various editions, was originally made up of representatives of the American Association of State Highway Officials and the National Conference on Street and Highway Safety,² but now has an equal number of representatives of each of those two organizations and of the Institute of Traffic Engineers.

This manual recognizes numerous developments in the field of traffic control and new needs resulting from higher traffic speeds since the last previous revision. Noteworthy are the advances in size, illumination, reflectorization, substitution of symbols for words, and other improvements to increase the effectiveness of signs; extension of the use and effectiveness of pavement markings; and developments in

¹The Uniform Vehicle Code and the Model Traffic Ordinance were prepared by the National Conference on Street and Highway Safety as standards for uniform motor-vehicle legislation, and are published by the Public Roads Administration.

²Since completing its contribution to this manual, the National Conference on Street and Highway Safety has been dissolved and its functions have been vested in the National Committee on Uniform Traffic Laws and Ordinances.

the use and design of islands. Important advances in the use of signals are also recognized, and part III includes discussion of the relative desirability of fixed-time and traffic-actuated signals under various conditions.

The manual contains the best existing judgment on several points on which research is now in progress or being arranged for by qualified agencies. Pending the completion of such researches the manual presents alternatives on some points, subject to certain fundamental specifications. Included in this category are certain details of Stop signs, no-passing-zone pavement markings, pedestrian signals, and the location of traffic control signals at intersections. In other similar cases the Joint Committee was able to agree on recommended standards though fully aware that there are differences in opinion and practice among able traffic engineers.

Because such questions, old and new, present a constant need for factual data, the Joint Committee has set up a continuing Subcommittee on Research. This subcommittee is to keep abreast of current research in the traffic field and to promote further studies needed for the standardization of traffic control devices. Future revisions of the manual thus can rest firmly on established facts of human behavior as affected by traffic control devices. To the Subcommittee on Research will be referred all questions that cannot promptly be answered from the experience of committee members or other qualified authorities.

Use and Misuse of Traffic Control Devices

Traffic control devices are increasingly necessary for regulating, warning, and guiding traffic. The details in this manual indicate their wide range and their proper application and operation.

Intersections are the most critical points in traffic control, and a large proportion of the control devices herein relate to intersections. Accurate determination of the degree of control, if any, needed at the intersection is highly important, as is proper selection of the design and operation details to effect that degree of control.

As previously stated, signs are required by law to indicate the applicability of certain traffic regulations. Adequate but not excessive use of warning signs, and sufficient well-designed and well-located route markers and destination signs also have great value in facilitating the orderly flow of traffic, as do well-considered pavement and curb markings and islands properly designed and located. Application of sound principles in the selection, installation, and operation of traffic signals is of the highest importance.

Misapplication of these traffic control devices, however, besides wasting public funds, has in numerous cases accomplished the reverse of the purpose intended, causing delay and confusion and promoting disrespect for and disregard of all control devices. In many communities the responsible authorities have not met problems relating to traffic control devices with scientific analysis but rather by haphazard experimentation. Two fundamental errors have been prevalent: (1) Placing traffic control devices without adequate study of the possible bad effect likely to result either where they are installed or at other points, and (2) in the case of traffic signals, operation in a manner and at times not justified by the conditions. The applicability of traffic control

devices in any specific case cannot be determined by guesswork. It should be based on sound engineering principles established by factual studies of types and flow of traffic, accidents, speeds, delays, and physical conditions that will show the exact nature of the difficulty and indicate what particular devices or methods of control are needed. To the extent now believed feasible, this manual sets forth warrants for the different types of traffic control devices.

Responsibility for Selection and Installation

There is wide variation in official responsibility for the selection, installation, and maintenance of traffic control equipment. In many cities the responsibility is placed upon some branch of the police department. In an increasing number of the more progressive cities it is under the direction of a traffic engineer. In a growing number of States, also, broad regulatory authority has been established over the installation and operation of all traffic control devices throughout the State, including small communities and rural areas that otherwise would not have the benefit of expert engineering advice. Thus important progress is being made toward uniformity. The design, installation, and maintenance of traffic control devices on State highways is recognized as being the responsibility of a traffic engineering division in the State highway department.

Until uniform laws replace the present wide variation in State laws regarding signs and signals, some jurisdictions may have to permit deviations from the recommendations of this manual. Fortunately, good progress is being made in bringing about the enactment of the desired uniform laws, and eventually such deviations will be reduced to a minimum.

While considerable equipment now in use does not conform to the standards here set forth, a large part of it can be brought to substantial conformity without excessive cost. Whenever new equipment is purchased or replacements are made because of the need of repairs or because of obsolescence, strict adherence to the standards herein should govern the selection.

Definitions applicable throughout the manual follow this introduction. Four general groups of traffic control devices in common use are then treated, as follows: Part I—Signs, part II—Markings, part III—Signals, and part IV—Islands.

Definitions

The following words and phrases, when used in this manual, shall be understood to have the meanings respectively ascribed to them:

1. Relating to the HIGHWAY:

Street or Highway.—The entire width between the boundary lines of every way publicly maintained when any part thereof is open to the use of the public for purposes of vehicular travel.

Roadway.—That portion of a highway improved, designed, or ordinarily used for vehicular travel, exclusive of the berm or shoulder. In the event a highway includes two or more separate roadways the term "roadway" as used herein refers to any such roadway separately but not to all such roadways collectively.

Pavement.—That portion of a roadway having a constructed surface to facilitate vehicular traffic.

Curb Line.—The boundary between a roadway and a sidewalk, usually marked by a fixed curb rising above the level of the roadway.

Sidewalk.—That portion of a street between the curb lines, or the lateral

lines of a roadway, and the adjacent property lines, intended for the use of pedestrians.

Cross Walk.—(a) That part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or, in the absence of curbs, from the edges of the traversable roadway.

(b) Any portion of a roadway, at an intersection or elsewhere, distinctly indicated for pedestrian crossing by lines or other markings on the surface.

Intersection.—(a) The area embraced within the prolongation or connection of the lateral curb lines, or, if none, then the lateral boundary lines of the roadways, of two highways which join one another at, or approximately at, right angles; or the area within which vehicles traveling upon different highways joining at any other angle may come in conflict.

(b) Where a highway includes two roadways 30 feet or more apart, then every crossing of each roadway of such divided highway by an intersecting highway shall be regarded as a separate intersection. In the event such intersecting highway also includes two roadways 30 feet or more apart, then every crossing of two roadways of such highways shall be regarded as a separate intersection.

Business District.—The territory contiguous to and including a roadway when within any 600 feet along such roadway there are buildings in use for business or industrial purposes which occupy 300 feet of frontage on one side or 300 feet collectively on both sides of the roadway.

Residence District.—The territory contiguous to and including a highway, not comprising a business district, when the property on such highway for a distance of 300 feet or more is in the main improved with residences or residences and buildings in use for business.

Rural District.—Any territory not included in a business or residence district as defined herein, whether or not within the boundaries of a municipality.

2. Relating to TRAFFIC:

Traffic.—Pedestrians, ridden or herded animals, vehicles, streetcars, and other conveyances either singly or together while using any highway for purposes of travel.

Pedestrian.—Any person afoot.

Vehicle.—Every device in, upon, or by which any person or property is or may be transported or drawn upon a highway, except devices moved by human power or used exclusively upon stationary rails or tracks.

Streetcar.—A car other than a railroad train for transporting persons or property and operated upon rails principally within a municipality.

Traffic Lane.—A strip of roadway intended to accommodate the forward movement of a single line of vehicles.

Official Traffic Control Devices.—All signs, signals, markings, and devices placed or erected by authority of a public body or official having jurisdiction, for the purpose of regulating, warning, or guiding traffic.

3. Relating to SIGNS:

Traffic Sign.—A device mounted on a fixed or portable support whereby a specific message is conveyed by means of words or symbols, officially erected for the purpose of regulating, warning, or guiding traffic.

Regulatory Sign.—A sign used to indicate the required method of traffic movement or use of the public highway.

Warning Sign.—A sign used to indicate conditions that are actually or potentially hazardous to highway users.

Guide Sign.—A sign used to direct traffic along a route or toward a destination, or to give information concerning places or points of interest.

4. Relating to MARKINGS:

Traffic Markings.—All lines, patterns, words, colors, or other devices, except signs, set into the surface of, applied upon, or attached to the pavement or curbing, or to objects within or adjacent to the roadway, officially placed for the purpose of regulating, warning, or guiding traffic.

Stop Line (or Limit Line).—A line behind which vehicles should stop when directed by a traffic officer, traffic control signal, Stop signal, or Stop sign.

Center Line.—A line marking the center of a roadway on which traffic moves in both directions, or dividing the roadway between traffic moving in opposite directions.

Lane Line.—A line other than a center line separating two traffic lanes.

Barrier Line.—A distinctive longitudinal pavement line which, when placed in proper relation to a normal center or lane line, or to another barrier line, indicates that all traffic must keep to the right thereof.

Delineator.—A reflecting device mounted at the side of the roadway, in series, to indicate the alinement of the roadway.

5. Relating to SIGNALS (*see also the glossary, appendix A*):

Highway Traffic Signal.—Any power-operated traffic control device, except a sign, by which traffic is warned or is directed to take some specific action.

Traffic Control Signal.—A highway traffic signal which, through its indications, alternately directs traffic to stop and permits it to proceed.

Fixed-Time Signal.—A traffic control signal which directs traffic to stop and permits it to proceed in accordance with a predetermined time schedule.

Traffic-Actuated Signal.—A traffic control signal which directs traffic to stop and permits it to proceed in accordance with the demands of traffic as registered by the actuation of detectors or push buttons.

(a) **Semi-Traffic-Actuated Signal.**—A type of traffic-actuated signal which provides means for traffic actuation on one or more but not all approaches to the signal location.

(b) **Full Traffic-Actuated Signal.**—A type of traffic-actuated signal which provides means for traffic actuation on all approaches to the signal location.

(c) **Speed-Control Signal.**—A type of signal in which means are provided for traffic actuation on some or all approaches and which provides Go indications in such a manner that vehicle speeds on one street are limited to a preselected maximum value.

Stop Signal.—A flashing red signal having the same function as a Stop sign.

Caution Signal.—A flashing yellow signal having the same general function as a warning sign.

6. Relating to ISLANDS:

Island.—An area within a roadway from which vehicle traffic is intended to be excluded, together with any area at the approach thereto occupied by protective deflecting or warning devices.

Pedestrian Island.—An island designed for the use and protection of pedestrians. Included are both loading and refuge islands.

Safety Zone.—The area or space officially set apart within a roadway for the exclusive use of pedestrians, and which is protected or is so marked or indicated by adequate signs as to be plainly visible at all times while set apart as a safety zone.

The foregoing definition of a safety zone is that contained in Act V of the Uniform Vehicle Code. A safety zone thus includes only the area intended to be occupied by pedestrians. For the purposes of this manual a pedestrian island includes the safety zone together with the area at the approach end occupied or outlined by protective deflecting or warning devices.

Loading Island.—A pedestrian island at a regular streetcar, bus, or trolley-bus stop especially provided for the protection of passengers.

Refuge Island.—A pedestrian island at or near a cross walk, to aid and protect pedestrians crossing the roadway.

Traffic Island.—An island designed to separate or direct streams of vehicle traffic. Included are both divisional and channelizing islands.

Divisional Island.—A traffic island, usually elongated and narrow, following the course of the roadway to separate traffic streams that flow in the same or opposite directions.

Channelizing Island.—A traffic island located to guide traffic streams along certain definite paths and to prevent the promiscuous movement of vehicles in what would otherwise be a widely extended roadway area.

Buffer.—A structure at the approach end of a safety zone designed to deflect or stop any vehicle which collides with it.

Prove.—An elongated extension of a buffer tapered and sloped downwards toward approaching traffic, so that a vehicle mounting it will drag thereon and come to a stop or reduce its speed considerably.

Jiggle Bars.—A series of raised transverse bars placed on the pavement to make any wheel encroachment within the area obvious to a vehicle operator without loss of control of the vehicle.

Part I

SIGNS

A—INTRODUCTION**Section 1.—Function of Signs**

The commonest device for controlling, safeguarding, or expediting traffic is the traffic sign. As in the case of any other type of traffic control device, signs must be used only where necessary and where justified by facts and field studies. Signs are not needed to confirm well known or universally recognized rules of the road, such as that requiring drivers to keep to the right, but they are essential where special regulations apply at specific places or at specific times only, or where hazards are not self-evident. They are also needed to give information as to highway routes, directions, destinations, and points of interest.

Section 2.—Legal Authority

Traffic signs shall be placed only by the authority of a public body or official having jurisdiction for the purpose of regulating, warning, or guiding traffic. No traffic sign or signal, or its support, shall bear any commercial advertising.

It is essential that signs be installed only under public authority; otherwise they may not be enforceable and violators will be dismissed in court. Signs placed without authority by private organizations do not fit the program, are often poorly placed and maintained, and are not legally binding. All unofficial and nonessential signs should be removed, as they weaken the value of the necessary signs.

This, however, should not prohibit authorizing public utility companies, without obtaining specific permission in each case, to erect temporary Men Working signs to protect equipment and workmen engaged in construction, maintenance, or repair work in a public highway, provided that such signs conform reasonably to the manual standards as to size, shape, and color. Some utility companies have found that smaller Men Working signs, on lower standards, and otherwise different in some details from those herein prescribed, are more effective for their purposes. Such signs should be permitted if approved by the proper authorities.

A suitable model for the legal authority for the placing of signs is presented in Act V of the Uniform Vehicle Code (secs. 19, 30-33, 37). Interference with official signs is prohibited in section 38 of the same act.

The regulations set forth by signs should be intelligently enforced. Otherwise, no matter how effectively the signs may be designed and placed, the results desired may not be obtained.

Section 3.—Classification of Signs

Functionally, signs are classified as follows:

Regulatory signs, giving the highway user notice of traffic regulations that apply at any given place or on a given highway, disregard of which constitutes a misdemeanor, and that would not otherwise be apparent.

Warning signs, calling attention to conditions in or adjacent to a highway or street that are potentially hazardous to traffic operations.

Guide signs, showing route designations, destinations, directions, distances, points of interest, and other geographical or cultural information.

Section 4.—Excessive Use of Signs

Care should be taken not to install too many signs, especially those of the regulatory and warning types which, if used to excess, tend to lose their authority. A conservative use of regulatory and warning signs is recommended. On the other hand, a frequent display of route markers and directional signs, judiciously placed, will not lessen their value.

Section 5.—Standardization of Signs

Modern highway speeds and increasingly complex intersections and interchanges require that highway signs be recognized and understood at a glance. Uniformity and simplicity in design, position, and application is of the greatest importance in aiding recognition. **All signs hereafter installed on any highway shall conform to the standards set forth in this manual.** In situations where messages are required other than those herein provided for, the signs shall be of the same shape and color as standard signs of the same functional type.

Section 6.—Standardization of Design

Uniformity in design includes shape, color, dimensions, symbols, wording, lettering, and illumination or reflectorization. The Public Roads Administration, on request, will furnish to State and local highway and traffic authorities, sign manufacturers, and similarly interested agencies, detailed drawings of the standard signs illustrated in this manual. These designs, both of symbols and of word messages, have been approved by the Joint Committee on Uniform Traffic Control Devices after a thorough review of the varying designs used in many States, supplemented by test studies. Standardization of these designs does not preclude further improvement by minor changes in the proportions of symbols, stroke-width and height of letters, width of borders, or in the lay-out of word messages, but **all shapes and colors shall be as indicated, all symbols shall be unmistakably similar to those shown, and where a word message is applicable the wording shall be as herein provided.**

Section 7.—Sign Shapes

The significance of sign shapes has been standardized as follows:

The octagon shape shall be reserved exclusively for the Stop sign, which requires that the driver shall stop near or at the point where the sign is located before proceeding cautiously.

The round shape shall be used exclusively for the advance warning of a railroad crossing.

Diamond-shaped signs shall be used only to warn of hazards either in the roadway or adjacent thereto.

Regulatory and informational signs shall be rectangular. Informational signs, as a rule, are rectangles with the longer dimension horizontal. Regulatory signs are ordinarily rectangles with the longer dimension vertical.

Special shapes are also reserved for other special purposes, e. g., the shield or other characteristic shape for route markers on U S and State highway routes, and the crossbuck for railroad crossings. In the rare cases where other shapes are desirable they may be used, but only with the approval of the official authority having jurisdiction.

Section 8.—Colors

Warning signs (including the round railroad-crossing sign) and Stop signs shall have a background of "highway yellow" with black symbols or lettering. In the case of the Stop sign a horizontal black panel with white or yellow reflectorized lettering may be used, or a white reflectorized panel with black lettering.

Yellow color cards showing the correct "highway yellow" shade for highway signs may be obtained from the Public Roads Administration on request.

Regulatory signs, other than the Stop sign and parking signs, shall have a white background and black letters. Parking signs shall have red or green lettering, depending on the type of restriction imposed.

Guide signs shall be black and white. Route Markers and auxiliary markers including Junction, Turn, and Directional Markers (M-1 to M-21, inclusive) shall have black letters or symbols on a white background. Destination, Distance, and Information signs shall have black letters on a white background or, optionally for enlarged or oversize signs, white letters on a black background.

Previous editions of this manual have specified that all guide signs use only black lettering on a white background. Tests have shown, however, that white lettering on a black ground is slightly more legible than the reverse arrangement. On the other hand, the black signs do not appear to be as effective in attracting attention by daylight. The black background, therefore, is made optional only for large signs, which are sufficiently conspicuous because of size alone. For improvement of their daytime visibility, a relatively wide white border is recommended.

Wherever white is specified herein as a sign color, it is understood to include aluminum or silver-colored reflecting coatings that reflect white light.

Section 9.—Dimensions

The sign dimensions shown in this manual are to be regarded as the minimum standard. Increases above this minimum are permissible and desirable where investigation has shown that a larger sign is needed for adequate emphasis. However, oversize signs should be used sparingly in order not to weaken the effect of smaller signs.

In determining whether the installation of an oversize sign is warranted, consideration should be given to such elements as highway speeds, the degree of hazard (as appraised by a field survey of sight limitations, intersection complications, etc., or as revealed by accident records), and the competition offered by other signs, lighting, or displays. Generally the use of oversize signs cannot be prescribed on the basis of arbitrary warrants. Each installation is a special case for study and decision.

In the enlarging of signs, standard shapes and colors shall be used, and standard proportions shall be retained, so far as practicable.

Section 10.—Symbols

Where practical, the standard signs use symbols rather than words to convey their messages. A simple conventional symbol like the curve arrow or the intersection diagram is instantly recognized. **Symbol designs shall in all cases be essentially like those shown in this manual.**

Details of symbols are shown on the sign drawings available from the Public Roads Administration.

Section 11.—Word Messages

Most sign messages, particularly those of regulatory and informational signs, cannot adequately be conveyed by symbols. Word messages should be as brief as possible. **Where applicable, standard wordings as shown in this manual shall be used.**

Section 12.—Lettering

Sign lettering shall be in clear, open capital letters of the type approved by the Joint Committee on Uniform Traffic Control Devices and its sponsoring agencies. Detailed drawings of these standard alphabets are supplied to highway departments and sign manufacturers by the Public Roads Administration.

The rounded style of the approved lettering, shown in all the sign illustrations herein, has been found by extensive tests to have better legibility, as well as a more pleasing appearance, than the former standard, which used straight lines and sharp bends throughout.

In no case should lettering be smaller than that shown in the illustrations herein, and in the sign drawings available from the Public Roads Administration.

Section 13.—Illumination and Reflectorization

Signs that carry messages of warning, important regulations, or essential directional information are at least as necessary by night as by day. **All warning signs, including railroad-crossing signs, all Stop signs, all other regulatory signs with the exception of pedestrian signs and urban parking signs, and, on State highways and important local roads, all guide signs, shall be illuminated or reflectorized.** Parking signs are ordinarily read at slow speeds and often receive some illumination from street lighting. Other exceptions to the general rule are the School sign and similar signs that have significance only during school or daylight hours, and the Men Working sign and other temporary signs, if used only during daylight.

Section 14.—Means of Illumination

Illumination may be by means of:

1. A light, within or behind the sign, illuminating the main message or symbol, or luminous tubing shaped to the lettering or symbol; or
2. An attached or independently mounted floodlight or floodlights, directed on the face of the sign.

Ordinary street or highway lighting is not regarded as meeting the requirements for sign illumination. However, such lighting can aid visibility to an appreciable degree and, if present, should be taken into consideration in selecting the exact points at which unreflectorized signs are placed.

All illumination shall be by white light, except that a flashing light incorporated in a sign installation shall be yellow when displayed with a warning sign or red when displayed with a Stop sign, in accordance with the signal code set forth in section 167 of this manual.

Section 15.—Means of Reflectorization

Reflectorization may be by means of:

1. Reflector buttons or units set into the symbol or message; or
2. Reflecting coatings, either on the sign background or, where a black background or panel is used, in the symbol or message.

All reflecting elements shall reflect white light, except that if a reflecting coating is used as a background of a yellow sign it shall reflect yellow light. If a black panel is used on the Stop sign the letters shall be reflectorized by clear reflector buttons or by white or yellow reflecting coating.

Reflector buttons in a highway sign are individual reflecting units arranged in rows or patterns to form the letters or symbols. In suitable sizes and spacings they give the visual effect of continuous lines or areas of light. Reflector buttons are made of glass or transparent plastic with lenses or prisms designed to reflect an incident beam of light directly back toward its source. It is this retrodirective reflection that distinguishes reflector buttons from any sort of specular or diffuse reflectors and gives them their great brilliance. An effective reflector button concentrates most of the reflected light into a narrow cone having only enough divergence to reach the driver's eyes in his normal position above the headlamps. This divergence angle should be on the order of one-half to one degree.

If made with multiple small prisms or lenses, reflector buttons need not be circular, though they remain essentially separate units.

A reflecting coating is a surfacing applied either to the background or to the symbol or lettering of a sign to give a uniformly brilliant reflection over the entire area so coated. The types of coating most commonly used are of retrodirective reflecting character, having minute glass spheres (or "beads") closely distributed and embedded in a flexible weather-resistant or painted surface. Each bead acts as an independent reflector button, but in mass effect the beads give the appearance of a uniformly brilliant area when viewed in the headlamp beam. A suitable incorporation of pigment in a reflecting coating causes it to reflect colored light, as for the yellow backgrounds of warning signs.

Sheets of polished metal so embossed as to produce a uniform pattern of small bright spots over the entire surface have also been used as reflecting coatings. These are diffuse rather than retrodirective reflectors, and consequently they reflect to the driver's eyes a part of the light from all sources within a fairly wide angular range. Their effective brilliance is not confined to a narrow cone around the axis of any incident light beam.

Reflecting coatings are particularly advantageous in signs having small lettering into which reflecting buttons cannot be fitted in a legible pattern. With a reflecting coating there is usually a minimum of difference between the daytime and nighttime aspects of a sign.

Individual reflectors or clusters of reflecting units, white or colored,

used to mark obstructions or to delineate a highway, are treated as markings, in part II of this manual.

Section 16.—Sign Borders

With rare exceptions, shown in the illustrations, all signs shall have a narrow border of the same color as the message, just inside the edge. This improves the appearance and, in the case of embossed metal signs, the embossed border adds materially to their rigidity. For 24-inch signs the border shall be from three-eighths to five-eighths inch in width, set in three-eighths inch from the edge, and for other sign sizes approximately in proportion. On metal signs, corners shall be rounded on a radius of $1\frac{1}{2}$ inches.

Section 17.—Standardization of Position

Standardization of position cannot always be attained in practice, because signs must in all cases be placed in the most advantageous positions, and must be accommodated to highway design and alinement. The general rule is to locate signs on the right-hand side of the roadway, where the driver is in the habit of looking for them. Signs in any other position should ordinarily be considered only as supplementary to signs in the normal location. Under some circumstances signs may advantageously be placed on channelizing islands, or overhead, or (as on sharp curves to the right) on the left-hand shoulder of the road, directly in front of approaching vehicles. In such cases the supplementary signs should be definitely more conspicuous than the signs normally placed. A supplementary sign located on the left of the roadway is often helpful on a three- or four-lane road, or on a one-way road, where traffic in the right-hand lane interferes with the driver's view to the right.

All signs shall be mounted approximately at right angles to the direction of, and facing the traffic that they are intended to serve.

Reflectorized signs should usually be turned a little toward the road to keep the incident angle of the headlight beams near 90 degrees throughout the range of useful visibility. Where mirror reflection from the sign face is encountered in such degree as to reduce the legibility of the signs, both nonreflectorized signs and those reflectorized with buttons should be turned slightly away from the road. At curved alinements the angle of placement should be determined by the course of approaching traffic, rather than by the roadway edge at the point where the sign is located. On grades it may be desirable to tilt a sign forward or back from the vertical, to improve the viewing angle.

Signs on the road shoulder should be not less than 6 feet nor more than 10 feet from the edge of the pavement or traveled way, except where conditions do not permit or where other requirements are specified with regard to particular signs elsewhere in this manual. Where a raised curb is present a sign should ordinarily be placed adjacent to the roadway, with its nearest edge at least 1 foot from the curb line.

Signs in rural areas should normally be mounted at a height of not less than $2\frac{1}{2}$ feet above the crown of the pavement to the bottom of the sign or, where several signs are placed on a single mounting, 2 feet to the bottom of the lowest sign. However, where parking is likely to occur, or where other obstructions are present, such as a

bridge handrail, the height should be at least 7 feet to the bottom of the sign. In business and in residence districts signs should be mounted at least 7 feet high to the bottom of the sign.

Overhead signs, whether in rural or urban areas, shall be not less than 14½ feet above the road surface, and preferably centered over the traffic lanes to which they apply.

Standard locations for a number of typical signs are illustrated in figures 1 and 2.

Warning signs are generally placed in advance of the condition to which they call attention, Stop signs as near as practicable to the point where the stop is to be made. Intersection guide signs are placed as shown in figures 8-10. Other signs are placed as required, in all cases as specified in the sections of this manual dealing with individual signs or classes of signs.

Section 18.—Standardization of Application

Important as is standardization with respect to design and placement, uniformity of application is at least equally important. Identical conditions should always be marked with the same type of sign, irrespective of where those particular conditions occur. **Each sign shall be displayed for one definite and specific purpose only.**

This manual sets forth criteria for the application and use of all types of signs. It is impossible, however, to set up specifications that can apply to every case. The proper signing of highways depends to a very great extent on the experience and good judgment of the engineer responsible for the placement and maintenance of signs.

Similar conditions in urban and rural areas should be treated in generally the same manner. It is recognized, however, that urban conditions differ from rural in respect to speeds, frequency of intersections, traffic congestion, parking, competing lights and displays, etc., and that in many instances signs must be differently applied and located. Where practical, therefore, this manual sets forth separate specifications for rural, residence, and business districts.

Before any new highway or any detour or temporary route is opened to traffic all necessary signs shall be in place.

Changes in the traffic characteristics of a highway may at any time call for a reappraisal of local sign requirements. **Signs required by road conditions or restrictions shall be immediately removed when those conditions cease to exist or the restrictions are withdrawn. Guide signs directing traffic to and on temporary routes or detours shall be removed when no longer applicable.**

Section 19.—Erection

Normally signs should be individually erected on separate posts, except where one sign supplements another, or where route or directional signs must be grouped. Two signs for different purposes should not be placed closer together than 100 feet along the highway if it can reasonably be avoided. Exceptions to this rule are sometimes necessary where space is limited, but the principle is sound. Two signs closely adjacent are difficult to read, especially at high speed.

This general rule applies to signs facing in opposite directions. To minimize distraction, such signs should not be placed immediately opposite each other on each side of the roadway.

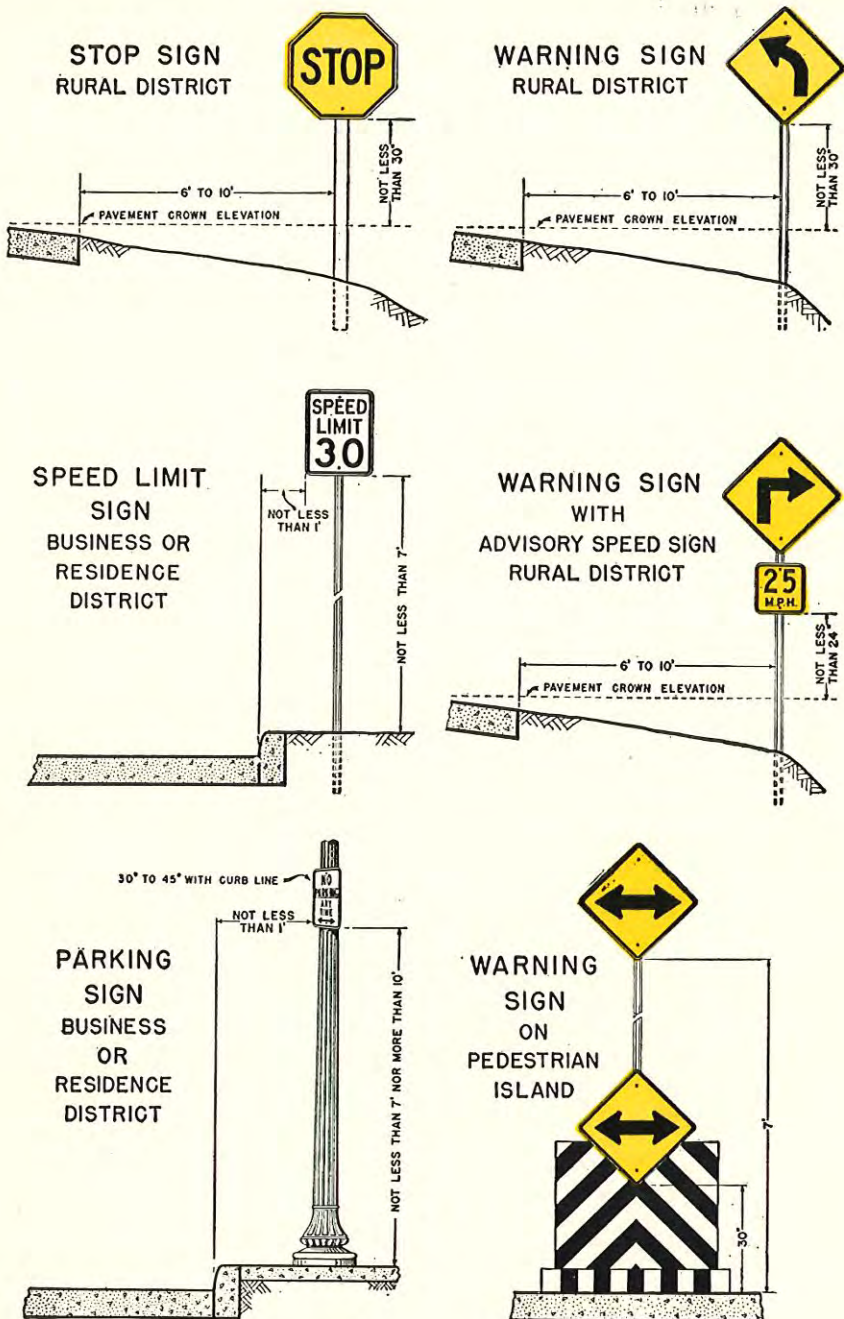


Figure 1.—Height and lateral location of signs—typical installations.

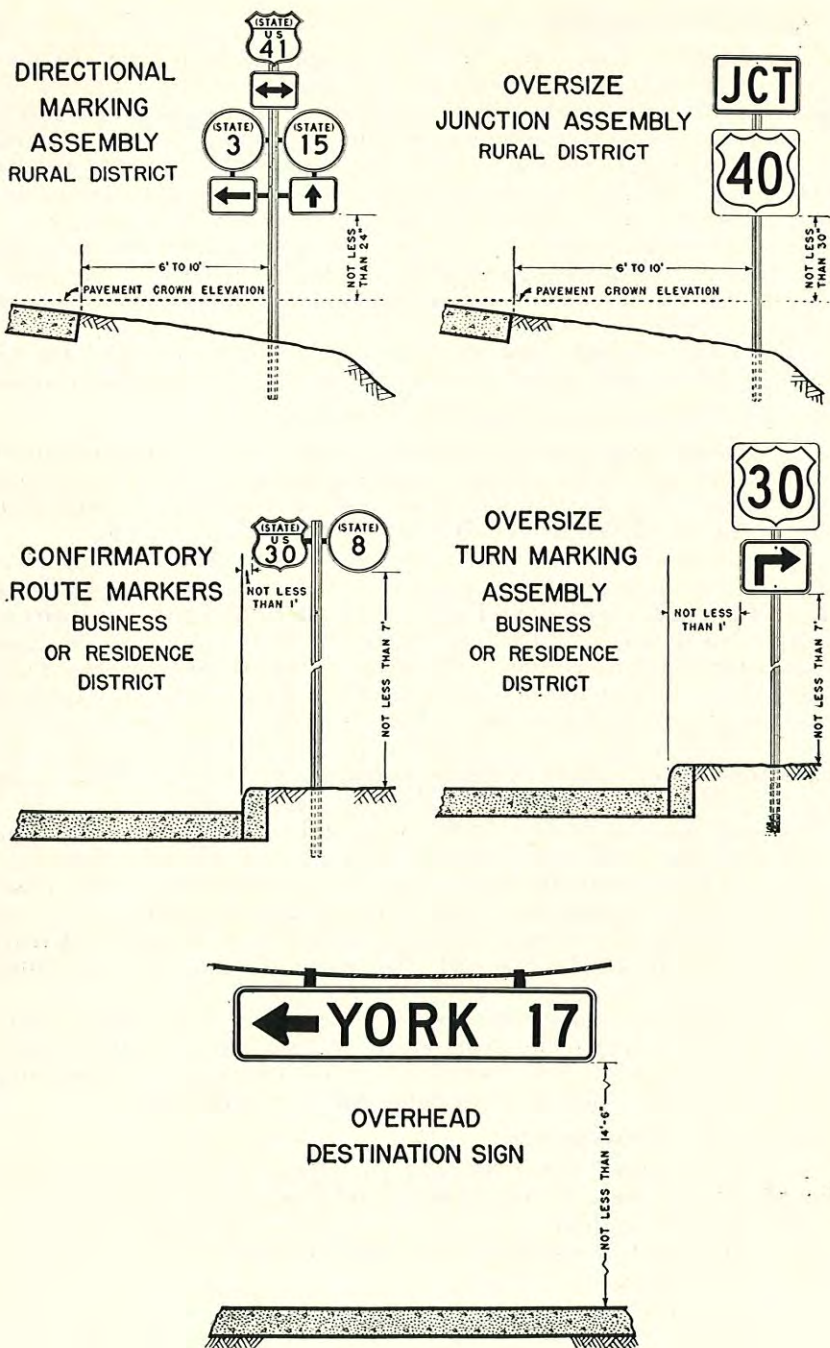


Figure 2.—Height and lateral location of signs—typical installations.

Section 20.—Materials

Metal treated with a rust-resistant coating has been generally used for permanent signs. Waterproof resin-bonded plywood and certain fiber materials when properly fabricated have also demonstrated satisfactory qualities for use under certain conditions. Wooden boards may be used for large signs and for temporary and seasonal signs, and heavy cardboard is adequate for temporary signs for special occasions or emergencies (see appendix B for suggested specifications).

It is recognized that technological progress may develop new and satisfactory, or superior, materials for highway signs. The above suggestions are not intended to exclude any other suitable materials now or hereafter available.

Noncorrosive bolts, screws, and washers shall be used for attaching permanent signs to their supports, to avoid discoloration.

Section 21.—Sign Posts and their Foundations

Sign posts and their foundations shall be so constructed as to hold signs rigidly in a proper and permanent position, and prevent them from swaying in the wind, or from being turned or otherwise displaced by children or irresponsible persons.

Sign posts for independent mounting should preferably be of metal or concrete, though wood is acceptable if well protected and treated against rot. Each State and municipality should adopt the material and design dictated by local resources and past practice as the most satisfactory and economical. Concrete or metal posts having holes spaced on 3-inch centers will fit the bolt holes of most of the standard regulatory and warning sign plates. For route marking assemblies and for certain other signs a 1-inch spacing is necessary, and metal posts punched or drilled on 1-inch centers are preferable. Wood posts may be drilled as desired at the time a sign is mounted.

In some cases, especially in business and residence districts, signs can be correctly placed on existing supports used for other purposes, such as traffic signal standards, street lamps, or public utility poles, thereby saving expense and minimizing sidewalk obstruction. Correct location of the sign should not thus be sacrificed, however. Utility poles should be used only with the permission of the controlling company.

A portable or removable type of mounting is desirable for Men Working, School, and similar signs used temporarily or intermittently. Such a mounting should be heavy enough not to turn over in the wind, and its base should not be appreciably wider than the sign.

Section 22.—Maintenance

All traffic signs shall be kept in proper position, clean, and legible at all times. Damaged signs shall be replaced immediately.

Signs poorly maintained lose their authority as traffic control devices. Damaged, defaced, or dirty signs are ineffective and discredit the agency responsible for them.

To insure adequate maintenance a suitable schedule for inspection, cleaning, and replacement of signs should be established. All signs should be inspected at least twice a year and any that are defective should be cleaned, touched up, or replaced and taken in for repair and refinishing or scrapping. Employees of the highway department, traffic police, and other governmental employees whose duties require

that they travel on the highways should be instructed to report any damaged or obscured sign at once.

Special care should be taken to see that weeds, shrubbery, construction materials, and snow are not allowed to obscure the face of any sign.

In the case of illuminated signs, a regular schedule of bulb replacement should be maintained, so that bulbs will be renewed before they would normally be expected to burn out.

Section 23.—Reflector Markers

Small reflecting units at the roadside have been widely used during recent years. These may be used to mark culverts and other hazards, or, in series, to indicate the alinement of the road. In the latter application they are known as delineators. Although, like signs, they are usually mounted on posts and convey a warning to the driver, they are more closely related to obstruction markings, or to guide lines. They are accordingly treated in this manual as markings, in part II, sections 155 to 157.

Section 24.—Major Routes

In respect to the application of certain signs reference is made to major routes. For the purposes of part I of this manual, dealing with signs, a major route is defined as a route that carries an annual average daily traffic of 2,000 vehicles or more. A signalized intersection is construed as an intersection of major routes.

The average daily traffic here referred to is the average 24-hour volume, not to be confused with the 8-hour counts used in establishing warrants for traffic signals in part III of this manual.

B—REGULATORY SIGNS

Section 25.—Application of Regulatory Signs

Regulatory signs shall be used to inform highway users of certain laws and regulations enacted to promote safety and convenience upon the streets and highways, the violation of which would constitute a misdemeanor. They are essential to indicate the applicability of legal requirements that would not otherwise be apparent. Great care must be exercised to see that they are erected wherever needed to fulfill this purpose, but unnecessary mandates should be avoided.

Regulatory signs shall be erected at those locations where the regulations apply, and shall be mounted so as to be easily visible to the motorist whose actions they are to govern. The message on the sign shall clearly indicate the requirements imposed by the regulation. Signs that have been erected but are no longer applicable shall be removed. All regulations set forth by signs should be zealously enforced. Otherwise, no matter how effectively the signs may be designed and placed, the results desired will not be obtained.

Although applicable regulations differ widely from one location to another, depending on traffic requirements, highway conditions, and local legislation, it is possible to establish uniform standards of application, location, size, shape, colors, and dimensions for different types of regulatory signs, so that the motorist can always recognize them quickly and be governed accordingly.

Section 26.—Classification of Regulatory Signs

Regulatory signs are classified in the following groups:

1. Stop sign (secs. 28-31).
2. Speed series (secs. 32-36).
3. Movement series (secs. 37-46):
 - (a) Turning (sec. 37).
 - (b) Signal (sec. 38).
 - (c) Alinement (secs. 39-42).
 - (d) Exclusion (secs. 43-44).
 - (e) One way (secs. 45-46).
4. Parking series (secs. 47-49):
 - (a) Prohibition (secs. 47-49).
 - (b) Restriction (secs. 47-48).
5. Pedestrian series (secs. 50-52).
6. Miscellaneous series (secs. 53-55).

Section 27.—Design of Regulatory Signs

With few exceptions, regulatory signs are rectangular in shape, with the longer dimension vertical. With the exception of the Stop sign, the Night Speed sign, and the parking signs, they are white, with black lettering and border. Stop signs are "highway yellow" with black lettering and border, the Night Speed sign has a black background, while parking signs are white with red or green lettering and border as specified. To improve the reflectorizing of the Stop sign a panel of black or reflectorized white coating may be applied across the center of the sign.

Minimum dimensions are given for each sign here specified. Where conditions require greater visibility, or where the required message cannot be accommodated on a smaller area, larger signs may be used, in which case all dimensions shall be increased approximately in proportion.



R-1
30" x 30"

Section 28.—Stop Sign (R-1)

It is commonly provided by law that State and local authorities, with reference to highways under their respective jurisdictions, may designate through highways and erect Stop signs at specified entrances thereto, or may designate any intersection as a stop intersection and erect like signs at one or more entrances to such intersection.

A suitable model for Stop sign legislation is to be found in Act V of the Uniform Vehicle Code (sec. 108).

Section 29.—Design of Stop Sign

Owing to the importance of Stop signs they are given a distinctive shape (octagon) and the color of a warning sign (yellow). The Stop sign not only notifies the motorist of a regulation that must be observed, but warns him of a potential hazard as well.

The STOP sign shall be octagonal in shape, shall have a yellow background, and shall carry the word STOP in letters at least one-third the height of the sign.

A variety of Stop sign designs are in use, including in addition to the basic standard of black letters on a yellow background, several arrangements of a horizontal panel intended to improve legibility, especially when reflectorized. California uses a red background, holding that red is the proper color to indicate a compulsory stop. The Joint Committee recognizes that there is at present no satisfactory evidence to favor one of the various designs as preferable to all others. It therefore specifies only that the Stop sign shall be octagonal and that it shall have a yellow background, in accordance with the accepted standard of 47 States. Arrangements have been made for research, from which it may be possible in the future to agree upon a single standard design that will be most effective both by day and by night, or perhaps different designs to meet specifically different conditions in rural and urban areas. Pending further information, however, the Committee recognizes a number of panel arrangements, and while for the sake of uniformity it specifies yellow as the standard background, it does not disapprove the red background in the absence of any conclusive evidence showing it to be less effective than the yellow.

The minimum size of Stop signs in rural districts shall be 30 inches by 30 inches. In residence and business districts a minimum size of 24 inches by 24 inches may be used where speeds are low, traffic is light, and mounting space is limited.

The 24-inch Stop sign that has been standard for many years is disproportionately small in relation to its importance, having an actual area less than 85 percent of that of the standard 24-inch warning sign. This manual accordingly establishes the 30-inch standard for general application. To expedite replacement the smaller signs should, where practicable, be relegated to less important roads and streets.

All Stop signs shall be illuminated or reflectorized.

Illumination may be by floodlight, by fixed white light or flashing red light in the letters, or by a flashing red signal in the face of the sign or just above it. The flashing red illumination should be kept in operation both by day and by night.

Reflectorization may be by: (1) A yellow reflecting coating covering the entire sign background; (2) white or clear reflecting buttons in the black letters; (3) a black horizontal panel in which white or yellow letters are made of reflecting coating or set with clear reflecting buttons; or (4) a white horizontal panel of reflecting coating on which the letters appear in black. Colored reflecting coatings other than those specified, or colored reflecting buttons, are not recommended. They tend to weaken the brilliance by night and to impair legibility by day. The panel, if used, should be just wide enough to accommodate the line of lettering, with necessary margins above and below the lettering.

Secondary messages on Stop signs, such as STATE HIGHWAY or THROUGH STREET, may be used but are not recommended.

Section 30.—Warrants for Stop Sign

Conditions warranting Stop signs are:

1. Intersection of a less important road with a main road where application of the normal right-of-way rule is unduly hazardous.
2. Intersection of a county road, city street, or township road with a State route.
3. Intersection of two main highways where no traffic signal is present.

4. Street entering a through highway or street.
5. Unsignalized intersection in a signalized area.
6. Railroad crossing where a stop is required by law or by order of the authority having jurisdiction over the highway or street.
7. Other intersection where high speed, restricted view, or serious accident record indicates a need for control by the Stop sign.

Stop signs should not ordinarily be erected at intersections where traffic signals are present. The conflicting commands of two types of control devices are confusing. If traffic is required to stop when the operation of Stop-and-Go signals is not warranted, the signals should be put on flashing operation with the red flasher facing the traffic that must stop.

In some States the meaning of a red flashing signal has not been established by law, and a Stop sign is necessary to make the requirement enforceable when the Stop-and-Go signal is not in operation. This condition should be remedied by legislation (See sec. 36 of Act V, Uniform Vehicle Code.)

Where two main highways intersect, especially at a Y intersection, and there is no priority to determine which direction of traffic should be stopped, a thorough study should be made. Although the flow of traffic may indicate that the Stop sign or signs should be placed on one highway, it is sometimes feasible in the interest of safety to stop the greater traffic volume in favor of the smaller.

The "Four-Way Stop" installation, where legal, has been found useful as a safety measure at some locations. Because of its delaying effect, it should be sparingly used. It should not be used unless the volume of traffic on the intersecting roads is about equal. Where there is any considerable volume of traffic, a traffic-signal installation is the more satisfactory solution.

Section 31.—Location of Stop Sign

Stop signs shall always be erected at the point where the vehicle is to stop or as near thereto as possible, and may be supplemented with a Stop line and with the word STOP on the pavement, as shown in figure 3. In no case shall a Stop sign be placed farther than 50 feet from the intersected roadway. As a general rule the distance should not exceed 15 or 20 feet, particularly in built-up areas.

In rural districts the Stop sign shall be placed not less than 6 feet nor more than 10 feet from the edge of the approach roadway or pavement. It shall be mounted so that its bottom will be 2½ feet above the crown of the roadway (fig. 1).

In residence and business districts, and at any place where parked vehicles may frequently obscure the Stop sign, the sign shall be mounted so that its lower edge will be 7 feet above the top of the curb. The left edge of the sign shall be not less than 1 foot nor more than 3 feet back from the face of the curb. Where there is a marked cross walk on the pavement the sign shall be erected 4 feet in advance of the cross-walk line nearest to approaching traffic.

Where only one Stop sign is used it shall be on the right-hand side of the roadway. At an intersection where a wide throat exists on the stop approach, the observance of the Stop sign may be improved by the erection of an additional Stop sign on the left side of the approach road, and by the use of a Stop line. At certain chan-

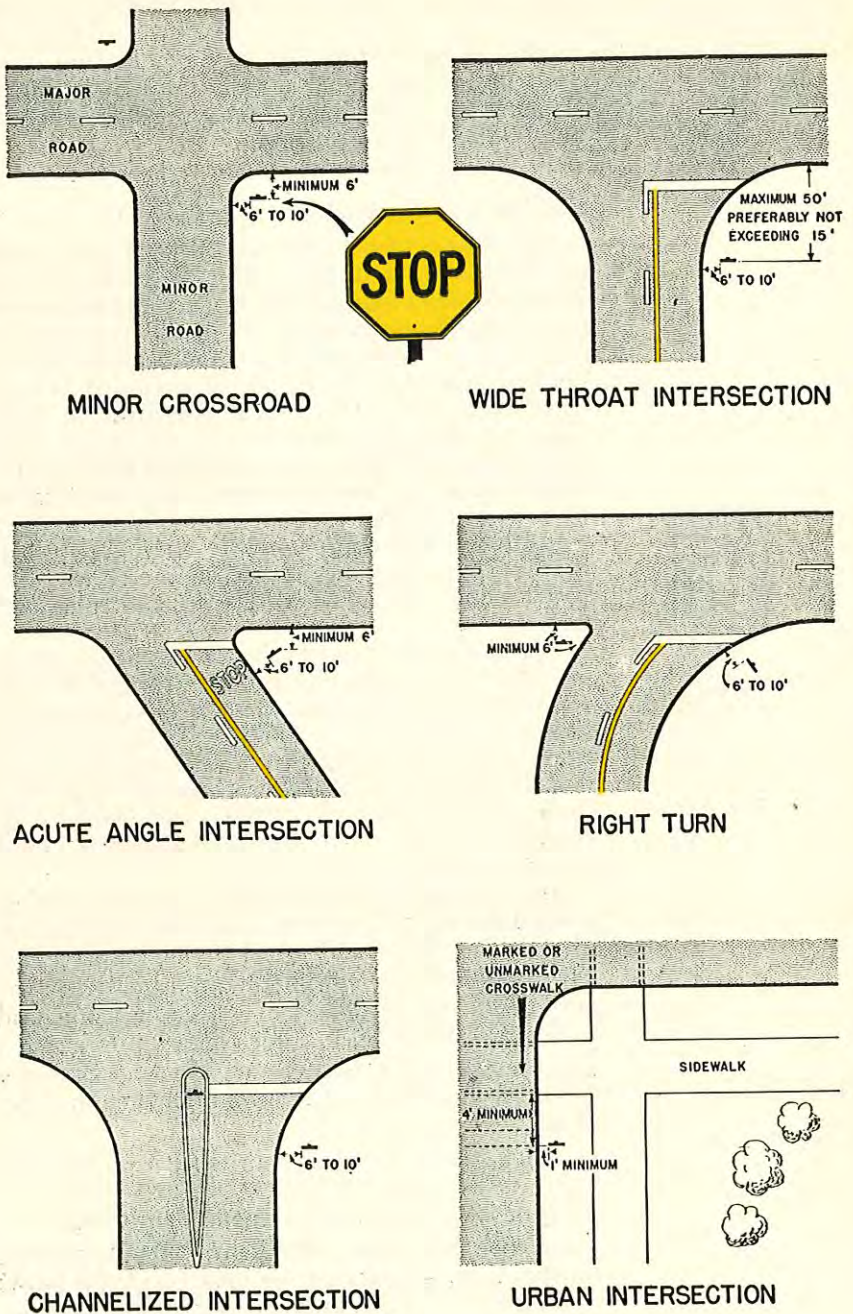


Figure 3.—Typical locations for Stop signs.

nelized intersections, Stop signs may be effectively placed on channelizing islands.

In the event the visibility of a Stop sign at any location is restricted, the sign shall be located as specified and a Stop Ahead sign (W-13, sec. 69) shall be erected not less than 350 feet nor more than 500 feet in advance of the Stop sign.

Figures 3, 8, 9, and 10 show typical Stop sign installations.

Section 32.—Speed Limit Sign (R-2)

The Speed Limit sign (R-2) shall be a vertical rectangle not less than 18 inches by 24 inches in size having black letters and numerals on a white background. On major routes, as defined in section 24, the sign should preferably be not less than 24 inches by 30 inches in size. Below the words SPEED LIMIT is shown in large numerals the speed limit in miles per hour. The limit that is displayed on this sign shall be the prima facie or absolute speed limit established by law, or a prima facie or absolute speed limit established after appropriate engineering and traffic investigation according to law. The speed limits shown should be in multiples of 5 miles.



R-2
18" x 24"
R-102
24" x 30"

A prima facie speed limit is a limit the exceeding of which is presumed under the law to be a violation; the defendant, however, having opportunity to prove that his speed was safe for conditions. At or below the prima facie speed the burden of proof is on the prosecution to show that there was a violation. Above the prima facie speed the burden shifts to the defendant to show that there was not a violation.

Speed legislation ordinarily specifies two or more different prima facie or absolute limits, applicable in urban and rural areas, respectively. The State highway authorities are usually further authorized, on the basis of an engineering and traffic investigation, to alter these limits at such places and times as they see fit. In some States, a special reduced limit is set for nighttime in rural areas.

A suitable model for speed limit legislation may be found in Act V of the Uniform Vehicle Code (secs. 56, 57).

Section 33.—Location of Speed Limit Sign

Speed Limit signs indicating statutory speed limits shall, when used, be located at the point of change from one type of district to another, and at additional locations within the district where it is necessary to remind motorists of the limit that is applicable.

In rural districts on U S and other State

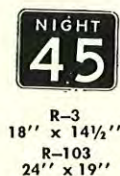
numbered routes Speed Limit signs indicating the statutory speed limits shall be erected at the entrance of the State and at boundaries of metropolitan areas. A special oversize sign is often desirable at State boundaries.

Signs indicating altered speed limits shall not be erected until the altered speed limits are approved and officially authorized. In such cases a Speed Limit sign shall be located at the beginning of each section where the speed is altered, and at appropriate intermediate locations. At the end of such sections there shall be erected a Speed Limit sign showing the next speed limit, or, in case there is no speed limit in the area about to be entered, an End (35) Mile Speed sign (R-5) shall be used.

Speed Limit signs shall be erected on the right-hand side of the road and shall face traffic approaching the section where the stated speed applies. In rural districts they shall be mounted so that the bottom edge of the signs will be $2\frac{1}{2}$ feet above the crown of the roadway except where parking of vehicles or other condition necessitates a higher mounting, and not less than 6 feet nor more than 10 feet from the edge of the roadway or pavement. In residence and business districts where there are curbs, the nearest part of the sign shall not be less than 1 foot back from the face of the curb. In districts where parking is permitted the signs shall be mounted so that the lower edge is not less than 7 feet above the top of the curb (fig. 1).

Section 34.—Night Speed Sign (R-3)

A special problem in speed signing is presented in States where different day and night speed limits are prescribed. Although posting both speeds destroys the effective simplicity of the standard speed sign, it seems necessary that the night limit be shown as well as the day limit. It is suggested that this be done by erecting immediately below the standard Speed Limit sign (R-2) or combining with it, a Night Speed sign (R-3) carrying the legend NIGHT (45). This should be 18 inches by $14\frac{1}{2}$ inches in size for use with the smaller speed sign, or 24 inches by 19 inches for use with the larger. The numerals in the Night Speed sign, and the words SPEED LIMIT in the standard sign, should be reflectorized. As a special but logical exception to the general color scheme, the Night Speed sign should have its legend in white upon a black background.



Section 35.—Speed Zone Ahead Sign (R-4)



R-4
18" x 24"
R-104
24" x 30"

The SPEED ZONE AHEAD sign may be placed in advance of an authorized speed zone to inform motorists that they are entering a section where the statutory limits have been altered. It shall have black lettering on a white background, and it shall be of the same size as the Speed Limit sign (R-2) at the beginning of the zone indicated. In rural districts it shall be placed not less than 300 nor more than 500 feet in advance of the speed zone. In all cases it shall be erected in the same manner as the Speed Limit sign (sec. 33).

This sign must always be followed by the regular Speed Limit sign erected at the beginning of the zone where the altered speed limit applies.

Section 36.—End (35) Mile Speed Sign (R-5)



R-5
18" x 24"
R-105
24" x 30"

The END (35) MILE SPEED sign may be displayed at the end of an authorized speed zone to inform motorists that they are leaving a section where the statutory speed limits have been altered. It shall have black lettering on a white background, shall be of the same size as the Speed Limit sign (R-2) at the beginning of the zone, and shall be erected in the same manner (sec. 33).

Section 37.—Turn Prohibition Signs (R-6 to R-9, inclusive)



R-6
18" x 24"

Turn Prohibition signs shall be used at intersections to indicate regulations prohibiting the types of turns specified. The NO U TURN sign may also be used between intersections on a wide roadway where dangerous U turns might be made. Where U turns are prohibited by statute throughout a given area, it is unnecessary to erect prohibitory signs at or between intersections as prescribed above.

Turn Prohibition signs shall be 18 inches by 24 inches in size except that when mounted below traffic signals where vertical clearance is limited they may be 14 inches by 9 inches in size (R-106 to R-109, inclusive). They shall have black lettering on a white background.

Where required at unsignalized intersections, the NO RIGHT TURN sign shall be placed on the near right-hand corner. Where NO LEFT TURN, NO U TURN, or NO TURNS signs are required two shall be used, one at the near right-hand and one at the far left-hand corner. Such signs shall be mounted, facing traffic approaching the intersection, so that the bottom part of the sign will not be less than 7 feet nor



R-107
14" x 9"

more than 10 feet above the top of the curb and so that no part of the sign will be less than 1 foot back from the face of the curb. At signalized intersections the signs shall be mounted just below the signal faces governing the traffic to which they apply. These are minimum requirements, and additional signs should be placed as necessary, at or in advance of the intersection. If advance signs are used, care should be taken that no alley or driveway exists between them and the intersection where the turning movement is prohibited. At an intersection with a one-way street, whether signalized or not, the One Way sign (sec. 45) should be used, rather than the Turn Prohibition sign.

A Turn Prohibition sign mounted on a traffic signal installed directly over any roadway shall have a clearance of at least $14\frac{1}{2}$ feet above the roadway.

When the movement restriction applies during brief periods only, the Turn Prohibition sign shall be mounted on a movable pedestal and placed in the roadway adjacent to the curb or in the middle of the intersection during such periods only.

Section 38.—Traffic Signal Speed Sign (R-10)

The Traffic Signal Speed sign, reading SIGNALS SET FOR (25) M. P. H., may be used to indicate the beginning of a section where the traffic control signals are coordinated into a progressive system and timed for a specified speed. The signs shall be 12 inches by 18 inches in size, with black lettering on a white background. Where used, they should be mounted on, or as near as possible to, each signal face where the timed speed changes, and at intervals of two blocks throughout any section where the timed speed remains constant.

Section 39.—No Passing Sign (R-11)

The NO PASSING sign may be used on two- and three-lane roads at the beginning of a zone through which restricted sight distance makes overtaking and passing hazardous. It shall have black letters on a white background, and be of a minimum size of 20 inches by 24 inches. It shall be erected at the right-hand side of the roadway, at a height of $2\frac{1}{2}$ feet to the bottom of the sign, not less than 6 feet nor more than 10 feet from the edge of the roadway. Because a driver about to pass a vehicle ahead often has only a restricted view to the right, an additional



R-8
18" x 24"



R-109
14" x 9"



R-10
12" x 18"



R-11
20" x 24"

sign on the left-hand side of the road may be desirable.

The sign normally should be supplementary to standard pavement markings as described in part II of this manual (secs. 134, 135). Where pavement markings are well maintained, and weather conditions are not likely to hide the markings, the No Passing sign need not be used.

Standards for determining the location and extent of no-passing zones are set forth in part II of this manual (sec. 136), in connection with pavement markings through such zones.

Section 40.—End No Passing Zone Sign (R-12)

The END NO PASSING ZONE sign may be used at the end of a no-passing zone where a No Passing sign has been erected at the beginning. It shall be of the same size and color, and shall be erected in the same manner as the No Passing sign.



R-12
20" x 24"

Section 41.—Keep Right Except to Pass Sign (R-13)

The KEEP RIGHT EXCEPT TO PASS sign may be used on multiple-lane pavements where motorists are required to keep in the right lane except when passing. It should be erected 300 feet to 500 feet from the beginning of a multiple-lane pavement, and at other locations where there is a tendency on the part of the motorist to drive in the inside lane or lanes when not passing.

This sign shall be a vertical rectangle 24 inches by 30 inches in size, with black lettering on a white background. It shall be placed on the right-hand side of the roadway, facing approaching traffic, with the bottom of the sign at a height of 2½ feet above the crown of the roadway, and not less than 6 feet nor more than 10 feet from the roadway edge.



R-13
24" x 30"

Section 42.—Keep Right Sign (R-14)

The KEEP RIGHT sign shall be used within and at the ends of median strips, parkways, loading islands, and refuge islands, at traffic islands, and at underpass piers, where traffic is required to keep to the right of such obstructions.

The sign shall be a vertical rectangle 18 inches by 24 inches in size, with black lettering and arrow on a white background. It should normally be mounted at a height of 2½ feet to the bottom of the sign.



R-14
18" x 24"

Where the obstruction is in or so near the line of traffic that the sign may be obscured by vehicles, a second sign of the same design should be mounted

directly above the standard sign with its bottom edge at a height of 7 feet above the pavement level.

On a median strip the Keep Right sign should be mounted about 50 feet beyond the approach end of the island. On a pedestrian island or inter-section-channelizing island it should be mounted at the approach end or as close thereto as practicable. The sign should be mounted on the face of or just in front of a pier or other obstruction in the center of the roadway, in which case the standard stripe markings on the obstruction (sec. 151) should be discontinued to leave a 3-inch space around the outside of the sign, as shown in figure 20.

Where traffic is permitted to pass to either side of an island or other obstruction in the roadway, the Double-Arrow warning sign should be used (W-30, sec. 86).

Section 43.—Do Not Enter Sign (R-15)

The DO NOT ENTER sign shall be conspicuously placed at the end of a one-way roadway or ramp to prohibit traffic from entering the restricted section. It shall be 24 inches square, with black lettering on a white background. It shall be mounted on the right-hand side of the roadway, facing traffic entering the roadway or ramp in the wrong direction. In rural districts it shall normally be erected at a height of 2½ feet to the bottom of the sign, and as close to the pavement edge as practicable, but with not less than 1 foot clearance to the nearest edge of the sign. In residence or business districts, or where a low mounting will not give adequate visibility, it shall be mounted not less than 7 feet nor more than 10 feet above the curb or roadway.



R-15
24" x 24"

Section 44.—Selective Exclusion Signs

The laws of some States permit the State or local authority having jurisdiction to exclude trucks or other commercial vehicles from any designated highway where signs have been placed giving notice thereof. These signs have not been satisfactorily standardized but NO TRUCKS, TRUCKS EXCLUDED, and COMMERCIAL VEHICLES EXCLUDED are suggested as suitably brief and specific messages.

Such signs shall be at least 18 inches by 24 inches in size and shall have black lettering on a white background. They shall be conspicuously placed at all entrances to the restricted roadway.

Where an unrestricted roadway intersects the restricted roadway the Exclusion sign shall be placed on the right-hand side of the restricted roadway approximately 25 feet from the intersection so as to be clearly visible to all drivers and others turning into the restricted roadway. A supplementary sign may be necessary on the left-hand side of the restricted roadway. In rural districts these signs shall normally be erected at a height of $2\frac{1}{2}$ feet to the bottom of the sign, and not less than 6 feet nor more than 10 feet from the roadway edge. In residence or business districts where a low mounting height will not give adequate visibility, they shall be mounted not less than 7 feet nor more than 10 feet above the curb or roadway. On entrance ramps or channelized roadways, or where a curb is present, they shall be as close to the pavement edge as practicable, with a minimum of 1 foot to the nearest edge of the sign.

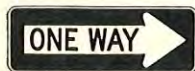
It is similarly provided in some States that the proper authority may exclude pedestrians, bicycles, or other nonmotorized traffic from controlled-access roadways, and shall erect signs setting forth such restrictions. No standardized message has been developed for such signs, but they should clearly indicate the type of traffic that is admitted, and, if necessary, the types that are excluded. They should be not less than 18 inches by 24 inches in size, with black lettering on a white background. They should be erected in the same manner as other Exclusion signs, described in the two preceding paragraphs.

A suitable model for exclusion legislation may be found in Act V of the Uniform Vehicle Code (secs. 75, 179).

Section 45.—One Way Sign (R-16)

The One Way sign shall be used to indicate streets upon which traffic is allowed to travel in one direction only. It shall consist of a white arrow symbol on a black horizontal rectangle 36 inches by 12 inches in size. Centered in the arrow shall be the words ONE WAY. The sign must be made in rights and lefts.

One Way signs shall be placed on the near right-hand and the far left-hand corners of the intersection so as to face traffic entering or crossing the one-way street (fig. 4). Where the intersection is signalized, the signs shall be placed below the appropriate signal faces. One Way signs shall also be placed parallel to the one-way street directly opposite the exits from driveways, alleys, and other publicly acces-



R-16
36" x 12"

sible places. A One Way sign should always be used, where applicable, rather than a Turn Prohibition sign.

At unsignalized intersections the One Way sign shall be mounted not less than 7 feet nor more than 10 feet above the top of the curb or pavement, and with no part of the sign less than 1 foot from the curb line.

Section 46.—Two Way Traffic Ahead Sign (R-17)



The TWO WAY TRAFFIC AHEAD sign shall be used on a one-way street in advance of an intersection beyond which the one-way traffic regulation does not apply. It shall be a vertical rectangle 18 inches by 24 inches in size, with black lettering on a white background.

This sign should not be used on a one-way connecting ramp or channelized roadway, or at the end of a divided stretch of highway, or at a T intersection where a one-way street ends.

The Two Way Traffic Ahead sign shall be placed on both the right- and left-hand sides of the street, not more than 25 feet from the intersection where two-way traffic is resumed (fig. 4). It shall be mounted not less than 7 feet nor more than 10 feet above the top of the curb, and with no part of the sign less than 1 foot back from the face of the curb.

Section 47.—Parking and Stopping Signs (R-18 to R-26, inclusive)

Parking signs and other signs governing the stopping and standing of vehicles cover a very wide variety of regulations and only general specifications can be laid down here. Typical examples are as follows:



- NO PARKING ANY TIME (R-18).
- NO PARKING 8:30 A. M.-5:30 P. M. (R-19).
- NO PARKING EXCEPT SUNDAYS AND HOLIDAYS (R-20).
- NO STOPPING OR STANDING (R-21).
- ONE HOUR PARKING 9 A. M.-7 P. M. (R-22).
- METER PARKING ONLY (R-23).
- DIAGONAL PARKING (R-24).
- NO PARKING LOADING ZONE (R-25).
- NO PARKING BUS STOP (R-26).

Other wordings will be found necessary to fit local conditions.

The legend on parking signs shall state whatever regulations apply, but the signs shall conform to the standards of shape, color, location, and use. Generally, parking signs should display such of the following information as is ap-

propriate, from top to bottom of the sign, in the order listed:

1. Restriction or prohibition.
2. Time of day it is applicable, if not at all hours.
3. Days of week applicable, if not every day.

In addition there should be a single-headed arrow pointing in the direction the regulation is in effect if the sign is at the end of a zone; or a double-headed arrow pointing both ways if the sign is at an intermediate point in a zone.

Successful use by a number of cities of parking signs mounted at a 90-degree angle with the curb line appears to justify the acceptance of such an arrangement as an alternative standard. In this case the arrow should be omitted, and a sign at either end of a parking zone should carry, if necessary, a small appended plate (R-27) reading THIS SIDE OF SIGN.

Where parking is prohibited at all times or at specified times, parking signs shall have red letters and border on a white background (Parking Prohibition signs); and where only limited-time parking is permitted, or where parking is permitted only in a particular manner, the signs shall have green letters and borders (Parking Restriction signs).

Where parking is prohibited during certain hours and permitted under a time limit at other periods of the day, two parking signs should ordinarily be used, the red above the green. As an alternative, both messages, in different colors, may be used on a single plate, with the sign lengthened vertically if necessary.

In residence and business districts, parking signs shall be 12 inches by 18 inches in size. Where several restrictions or qualifications must be set forth, the vertical length of the sign may be increased as necessary. In rural districts, the size of the sign may be increased to 24 inches by 30 inches.

At the transition point between two parking zones it may be advantageous to use, instead of two signs, a single sign 20 inches by 18 inches. This is, in effect, two standard signs mounted side by side. Such a sign should display a right and a left arrow pointing in the directions that the respective restrictions apply. (R-28.)

Section 48.—Placement of Parking Signs

Parking signs in residence and business districts shall be mounted not less than 7 feet nor more than 10 feet above the top of the curb, and with no part of the sign less than 1 foot back from the face of the curb. They should be



R-19
12" x 18"



R-22
12" x 18"



R-26
12" x 18"

set at an angle of not less than 30 degrees nor more than 45 degrees with a line parallel to the flow of traffic so as to be visible to approaching traffic (fig. 1).

Care should be exercised to see that the single arrows point in the proper direction to indicate the regulated zone. Where the zone is longer than 200 feet, signs showing a double arrow will be needed at intermediate points within the zone, at intervals not exceeding 200 feet.

Mounting at an angle of 90 degrees with the curb line is also acceptable. In this case two signs must be mounted back to back at a transition point between two parking zones, each with the appended plate reading THIS SIDE OF SIGN (R-27). At intermediate points within a zone a single sign without any arrow or appended plate should be used. Otherwise standards for placement should be the same as specified above.

Section 49.—Parking Signs in Rural Districts

In rural districts NO PARKING ON PAVEMENT signs (R-29) may be used to emphasize the provisions of law that no person shall stop, park, or leave standing any vehicle upon the paved part of the highway where it is practical to leave such vehicle off such part of the highway. The signs should be used primarily at points of scenic beauty or other points of interest where violations are prevalent, and where stopping or parking on the pavement obstructs the normal flow of traffic. If necessary the sign may be made to read NO STOPPING ON PAVEMENT (R-30).



R-29
24" x 30"

These signs shall be 24 inches by 30 inches in size, using red letters and border on a white background. They shall be mounted at right angles to the pavement, facing approaching traffic, and not less than 6 feet nor more than 10 feet from the edge of the pavement. They should ordinarily be reflectorized. Where off-pavement parking is likely to occur, they should be mounted not less than 7 feet nor more than 10 feet above the pavement level. If parking is not practical, they should be at a height of 2½ feet to the bottom of the sign. They should be located at those points where hazardous parking is likely to occur, and at necessary intervals throughout any section where the condition exists.

Section 50.—Walk on Left Sign (R-31)

On rural highways where no sidewalks are provided, a pedestrian sign WALK ON LEFT FACING TRAFFIC may be used to encourage safer pedestrian habits. This sign shall be 18

inches by 24 inches in size, with black lettering on a white background. It should be erected, ordinarily on the right-hand side of the road, where pedestrians must walk on the pavement or road shoulder in the absence of pedestrian pathways or sidewalks. It is particularly desirable at the edge of built-up districts, where sidewalks are discontinued. It should be mounted at a height of $3\frac{1}{2}$ feet to the bottom of the sign, and at the outside edge of the usable shoulder of the road.

Section 51.—Pedestrian Crossing Signs (R-32 to R-35, inclusive)

Pedestrian Crossing signs may be used to supplement traffic-signal control, or to aid in limiting pedestrian crossing to safe places. They will ordinarily be required only in business districts or at signalized intersections. The following messages are typical:

CROSS ON GREEN LIGHT ONLY (R-32).
CROSS ON WALK SIGNAL ONLY (R-33).
CROSS ONLY AT CROSS WALKS (R-34).
NO PEDESTRIAN CROSSING (R-35).

Pedestrian Crossing signs shall be 12 inches by 18 inches in size, with black letters on a white background. They shall be erected to face pedestrians about to cross the roadway, at a height of approximately 7 feet to the bottom of the sign. Where signals are present, an appropriate location is on the posts supporting the signals.

Section 52.—Pedestrian-Actuated Signal Sign (R-36)

The Pedestrian-Actuated Signal sign should be used where it is desired to enforce pedestrian observance of traffic-actuated signals. To permit pedestrians to register a demand for the Go signal a pedestrian push button should be conveniently mounted on a post at each end of each cross walk controlled by the traffic-actuated signals. Such a push button should be at a height of from $3\frac{1}{2}$ to 4 feet above the sidewalk, and the Pedestrian-Actuated Signal sign, reading PUSH BUTTON FOR GREEN LIGHT, should be mounted immediately above it.

The sign shall have black lettering on a white background, and shall be 8 inches by 10 inches in size.

Section 53.—Road Closed Sign (R-37)

The ROAD CLOSED sign shall be used to mark roads that have been closed to all traffic (except the contractor's equipment and such vehicles as may be permitted to enter for access



R-31
18" x 24"



R-32
12" x 18"



R-36
8" x 10"



R-37
40" x 24"

to residences on the closed portion of the road) either because of construction or maintenance operations or because of a temporary emergency such as high water or a landslide. It should not be used where traffic is maintained or where a route is detoured several miles in advance of the actual construction or blockade.

The Road Closed sign shall be 40 inches by 24 inches in size, with black lettering on a white background. It shall be illuminated or reflectorized.

The sign shall be mounted on a barricade in the center of the roadway or directly facing traffic on the right half of the roadway, at a height of $2\frac{1}{2}$ feet to the bottom of the sign. If a temporary or detour route begins at the barricade, a Temporary Route assembly with a directional arrow (sec. 107) or a Detour sign (sec. 111) should be mounted just below the Road Closed sign, with the lowermost part of the assembly not less than 2 feet above the road surface.

Section 54.—Load Limit Sign (R-38)

Due to seasonal weakening of the road surface, obsolescence of bridges or pavement, or other impairment of a roadway, it is often necessary to limit the load permitted on a roadway. The Load Limit sign, reading **LOAD LIMIT 10 TONS**, shall be used to indicate such restrictions. The sign shall be 18 inches by 24 inches in size, with black lettering on a white background. It shall be located immediately in advance of the bridge or other structure to which the restriction applies. In the case of an extended length of road, the sign shall be placed on the right-hand side of the restricted roadway approximately 25 feet from any intersecting road on which the restriction does not apply, so as to be clearly visible from all vehicles turning into the restricted roadway. A supplementary sign may be necessary on the left-hand side of the roadway. If the limit applies at an intermediate point where there is no alternate routing, a special sign should be provided to divert heavy vehicles at the nearest intersection where a suitable detour is available.

Load Limit signs in rural districts shall normally be erected at a height of $2\frac{1}{2}$ feet to the bottom of the sign, and not less than 6 feet nor more than 10 feet from the roadway edge. In residence or business districts where a low mounting height will not give adequate visibility they shall be mounted not less than 7 feet nor more than 10 feet above the curb or roadway. On entrance ramps or channelized



R-38
18" x 24"

roadways, or where a curb is present, they shall be as close to the pavement edge as practicable, with a minimum of 1 foot to the nearest edge of the sign. At bridges they may be mounted on the bridge structure.

Section 55.—Other Regulatory Signs

Regulatory signs other than those specified above may be required to aid the enforcement of other laws or regulations. They should be of adequate size, and designed with black lettering on a white background, on rectangular plates with the longer dimension vertical. They should be mounted in accordance with the general requirements for sign position (sec. 17), or as necessary to make them most effective.

Typical miscellaneous regulatory signs are TRACTORS WITH LUGS PROHIBITED, WET PAINT — DO NOT CROSS LINE, NO DUMPING ALLOWED, NO HITCH HIKING, and NO FISHING FROM BRIDGE. The uses for such signs are sufficiently obvious to require no detailed specifications.

C—WARNING SIGNS

Section 56.—Application of Warning Signs

Warning signs, as their name implies, shall be used for the purpose of warning traffic of hazardous conditions either on or adjacent to the road. Warning signs require caution on the part of the motorist and generally call for reduction of speed in the interest of his own safety and that of other motorists and pedestrians. Adequate warnings are of great assistance to the vehicle operator and are valuable in safeguarding and expediting traffic. However, the use of warning signs should be kept to a minimum. Too frequent use of them tends to breed disrespect for all signs. Improved highway design generally reduces the need for warning signs.

Typical locations and hazards that may warrant the use of warning signs are:

1. Turns (secs. 59, 68).
2. Curves (sec. 60).
3. Reverse turns and curves (secs. 61, 62, 68).
4. Successions of curves, with or without short tangents (sec. 63).
5. Intersections (secs. 64-67).
6. Advance warnings of Stop signs and traffic signals (secs. 69, 70).
7. Grades, dips, and bumps (secs. 71-73).
8. Changes in pavement widths (secs. 74-77).
9. Narrow roadways, bridges, and other points of limited clearance (secs. 78-80).
10. Road construction or repairs (secs. 81-83).
11. Other temporary road conditions (secs. 84, 85).
12. Pedestrian islands or similar obstructions (sec. 86).
13. School zones (sec. 87).
14. Railroad crossings (secs. 88, 89).
15. Entrances and crossings (sec. 90).

Determination of the sign to be erected shall be in accordance with the criteria set forth in the following pages. When doubt exists as to which sign to use, the one requiring the minimum restriction shall be erected.

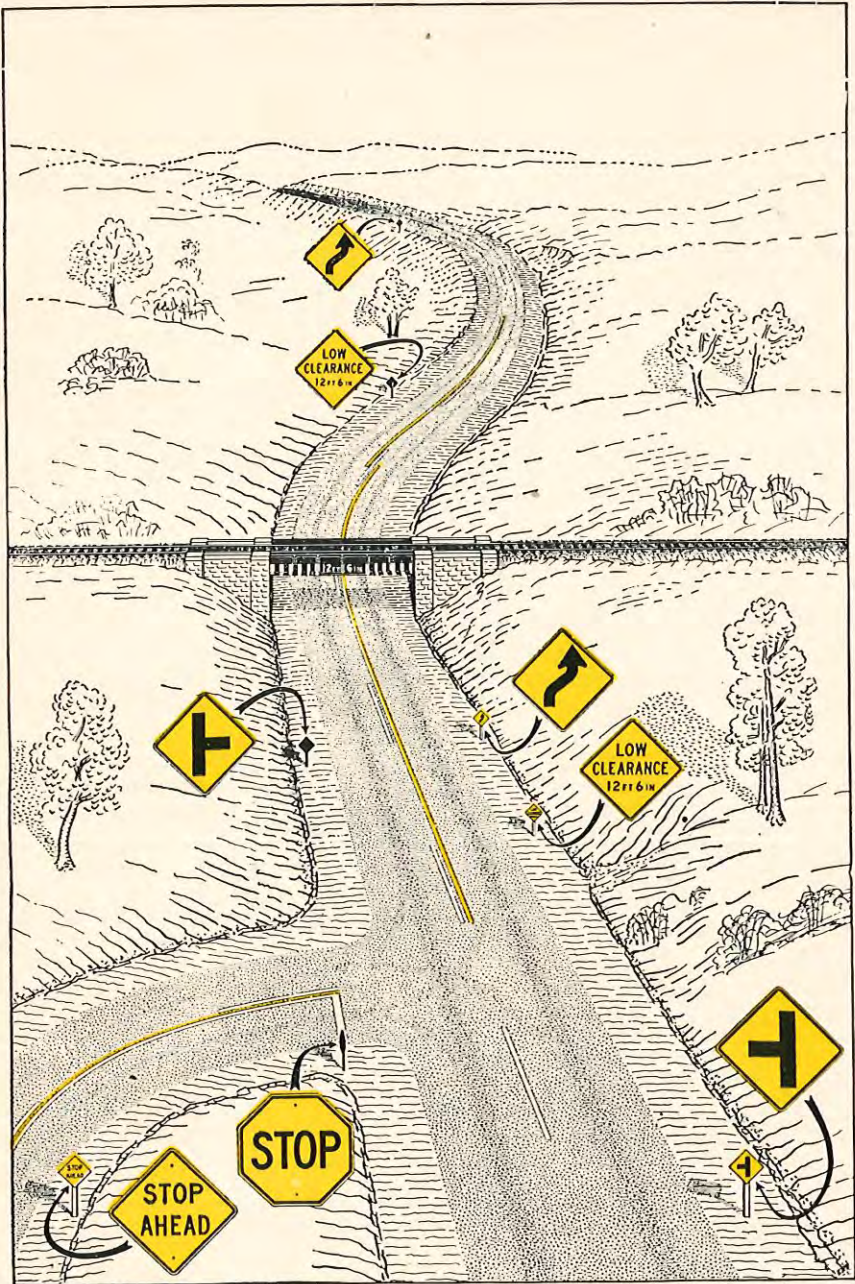


Figure 5.—Typical applications of warning signs.

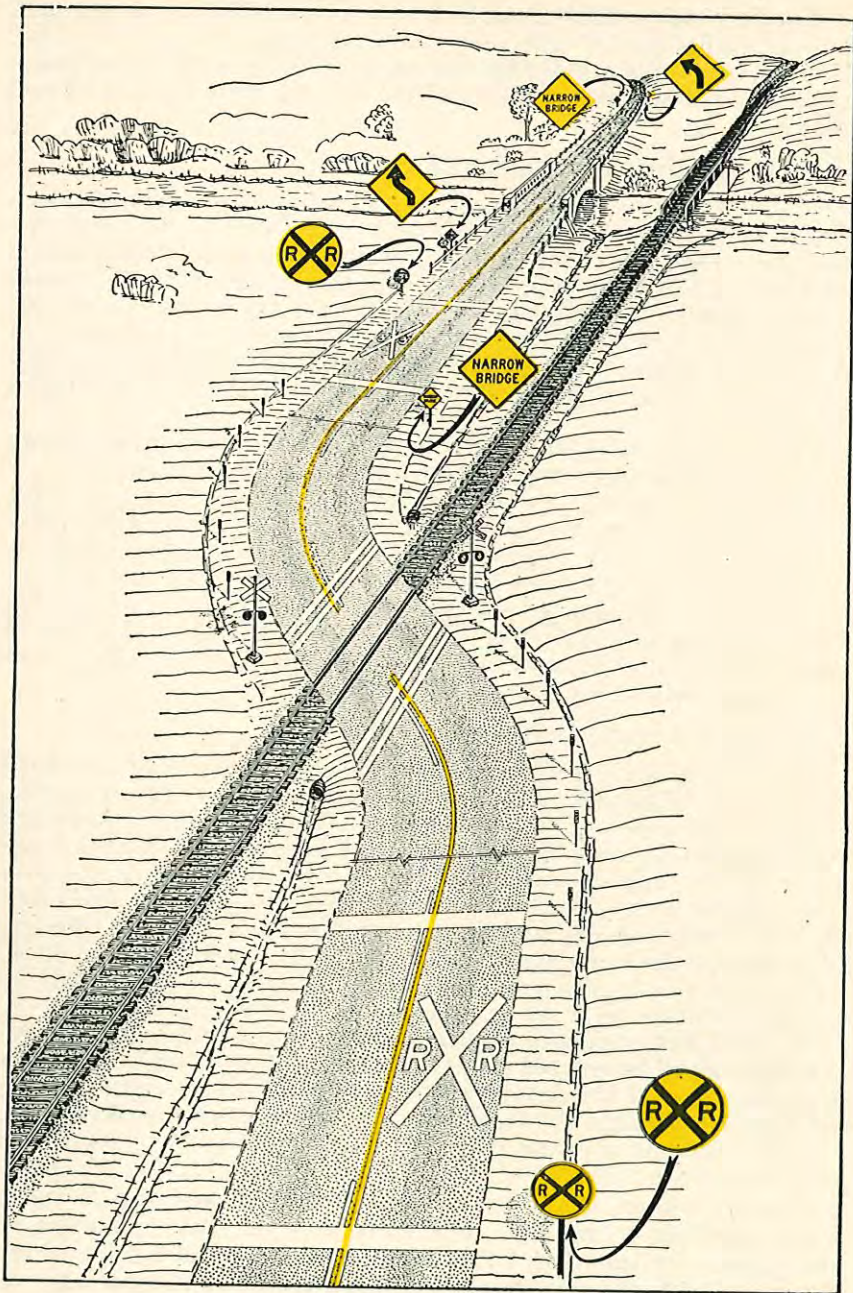


Figure 6.—Typical applications of warning signs.

Warning signs shall be applied only as specified in this manual. Those specified herein cover most conditions that are likely to be met. **If other warnings are needed the signs shall be of standard shape and color for warning signs, and the messages shall be brief and simple.**

Section 57.—Design of Warning Signs

Warning signs convey their message by legend or symbol, color, and shape. All, with the permissible exception of the Large Arrow sign (sec. 68), shall have a "highway yellow" background, with black lettering or symbols. They shall be diamond shaped (square with one diagonal vertical) with the exception of the Railroad Advance Warning sign, which shall be circular; the Railroad Crossbuck sign; the Large Arrow sign, which shall be a horizontal rectangle; and the Advisory Speed sign, which shall be square.

All warning signs shall be reflectorized or illuminated unless, like the School sign, they have significance only by day.

The sizes of signs here shown are to be regarded as minimum sizes. Where conditions require greater visibility or emphasis, larger signs should be used, with symbol or legend enlarged approximately in proportion to outside dimensions. The minimum standard size for warning signs, unless otherwise specified, is 24 inches by 24 inches. On rural highways three or more lanes in width the minimum size of warning signs should be 30 inches by 30 inches. (These dimensions are measured along the sides of the diamond.)

Section 58.—Location of Warning Signs

Since warning signs are placed primarily for the protection of the driver who is unacquainted with the road, it is very important that thought and care be given to their location and erection. Although it is specified herein at what distances the signs shall be placed in advance of the hazards warned against, there will be many instances where physical conditions will require different distances. Trial runs should be made by day and by night to determine the most effective location and erection characteristics for each installation. In cities, where speeds are relatively low, warning signs should usually be placed nearer to the points of hazard than on rural highways.

In rural and residence districts where no parking occurs, warning signs shall be erected not less than 6 feet nor more than 10 feet from the edge of the pavement or traveled roadway, with the lowest edge of the sign $2\frac{1}{2}$ feet above the crown of the roadway (fig. 1). In any location where they will obstruct sidewalks or pedestrian paths, however, they should be mounted at a height of not less than 7 feet to the bottom of the sign. In residence and business districts where parking is frequent, they shall be so set that the bottom of the sign is not less than 7 feet above the top of the curb, and the left-hand edge not less than 1 foot back from the outside edge of the curb.

Signs indicating conditions that are temporary or intermittent in occurrence, such as road repairs, should be mounted on portable standards so that they can be set up and removed as required.

Figures 5 and 6 show typical installations of warning signs.

Section 59.—Turn Sign (W-1)

The Turn sign, showing an arrow bent at a right angle (W-1, right or left), shall be used to mark curves having a curvature of 28 degrees and over, and to mark other curves having a curvature of from 15 degrees to 27 degrees when the central angle exceeds 45 degrees (see fig. 7 for a method of measuring curvature). All curves should be marked with Turn signs when a ball-bank indicator shows banks of 10 degrees or more at speeds less than 31 miles per hour. All Turn signs shall be reflectorized. Where a Turn sign is warranted, a Large Arrow sign (sec. 68) shall be used on the outside of the turn. Additional protection may be provided by use of the Advisory Speed sign (W-35, sec. 91).

The Turn sign shall be erected not less than 350 feet nor more than 500 feet in advance of the beginning of the turn, and in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 60.—Curve Sign (W-2)

The Curve sign, showing a curved arrow (W-2, right or left), shall be used to mark a curve having a central angle of less than 45 degrees and a curvature of from 4 to 28 degrees, and to mark all other curves having a curvature between 4 degrees and 15 degrees and a central angle greater than 45 degrees (see fig. 7 for a method of measuring curvature). An alternative warrant for use of the sign is a ball-bank indicator reading of 10 degrees or more at speeds between 31 and 60 miles per hour. A Turn sign (W-1) and Large Arrow sign (W-11) should be used where curvature exceeds that specified.

All Curve signs shall be reflectorized. Additional protection may be provided by the use of the Advisory Speed sign (W-35, sec. 91).

The Curve sign shall be erected not less than 300 feet nor more than 500 feet in advance of the beginning of the curve, and in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 61.—Reverse Turn Sign (W-3)

Where two turns in opposite directions, as defined in the warrants for Turn signs (sec. 59), are separated by a tangent of less than 400 feet, a Reverse Turn sign shall be used, showing an arrow bent twice in opposite directions at right angles. If the first turn is to the right, a Right Reverse Turn sign (W-3-R) shall be used, and if the first turn is to the left, a Left



W-1
24" x 24"



W-2
24" x 24"



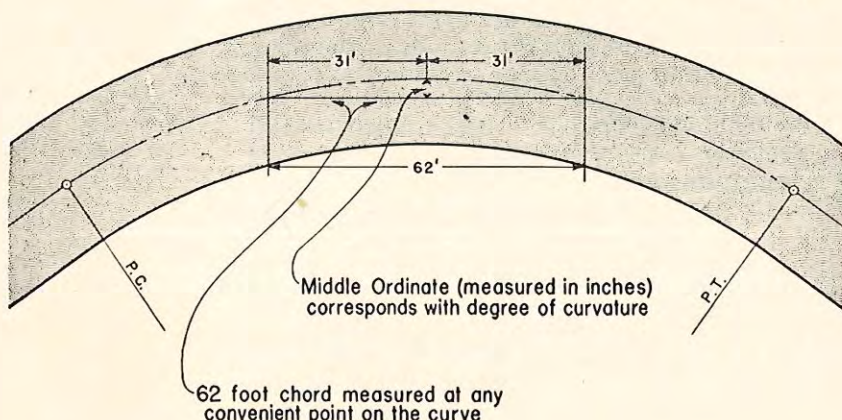
W-3
24" x 24"

Reverse Turn sign (W-3-L). All such signs shall be reflectorized. For additional protection the Advisory Speed sign (W-35, sec. 91) may be used.

The Reverse Turn sign shall be erected not less than 350 feet nor more than 500 feet in advance of the first turn, and in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 62.—Reverse Curve Sign (W-4)

Where two curves in opposite directions, as



Central angle may be determined by multiplying the length of curve from P.C. (beginning of curve) to the P.T. (end of curve) by the degree of curvature (as found above) and divide that product by 100'.

Example: $\frac{500'(\text{length of curve}) \times 5^\circ(\text{inches at middle ordinate})}{100'} = 25^\circ \text{ central angle}$

Degree of curvature	Radius of curve (feet)	Central angle (degrees)	Sign required
0-3	2000 and over	all	none
4-14	400 to 1500	all	Curve
15-27	200 to 400	under 45	Curve
15-27	200 to 400	45 and over	Turn
28 and over	under 200	all	Turn

Figure 7.—Method for determining degree of curvature and central angle of horizontal curves.

defined in the warrants for Curve signs (sec. 60) are separated by a tangent of less than 400 feet, a Reverse Curve sign shall be used, showing an arrow curved twice in opposite directions. If the first curve is to the right, a Right Reverse Curve sign (W-4-R) shall be used, and if the first curve is to the left, a Left Reverse Curve sign (W-4-L). All such signs shall be reflectorized. For additional protection the Advisory Speed sign (W-35, sec. 91) may be used.

The Reverse Curve sign shall be erected not less than 300 feet nor more than 500 feet in advance of the first curve, and in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 63.—Winding Road Sign (W-5)

The Winding Road sign showing an arrow bent four times in opposite directions shall be used where there is a series of five or more turns or curves, as defined in the warrants for Turn and Curve signs, separated by tangent distances of less than 400 feet. If the first turn or curve is to the right, a Right Winding Road sign (W-5-R) shall be used, and if the first turn or curve is to the left, a Left Winding Road sign (W-5-L). All Winding Road signs shall be reflectorized.

Additional protection may be provided by the installation of road-delineation markers as described in part II of this manual (sec. 157), and by use of the Advisory Speed sign (W-35, sec. 91). Where there are fewer than five curves in succession, one or more Reverse Turn or Reverse Curve signs should be used.

The Winding Road sign shall be erected at the beginning of the first series of curves. In advance of this sign either a Turn or a Curve sign shall be erected showing the direction of the first curve. These signs shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 64.—Cross Road Sign (W-6)

The Cross Road sign, showing the vertical cross symbol, shall be erected on a through highway to indicate the presence of a cross road. Its use should be restricted to intersections with roads that are improved to such an extent that there is likely to be a fairly large volume of traffic entering or crossing the through route and where unusual features, such as poor sight distance or obscured entrances, make it advisable that the intersection be called to the motorist's attention. It should not ordinarily be



W-4
24" x 24"



W-5
24" x 24"



W-6
24" x 24"

used where Junction signs or Turn Markers are present. **Cross Road signs shall not be erected at unimproved intersecting roads.** Stop signs (sec. 28) on the secondary road are far more effective than Cross Road signs on the main road. Too frequent use of the Cross Road sign should be avoided.

More complex intersections, or oblique crossings, may be shown by appropriate diagrams.

If there is a considerable difference in the importance of the intersecting roads, the more important route should be shown by a heavier line in the diagram. Since this requires the stocking of several different designs, however, and since a turn in a numbered route is shown by Route Markers, the use of different widths of line is not mandatory.

The Cross Road sign shall be erected not less than 300 feet nor more than 500 feet in advance of the intersection, and in accordance with general specifications for the placement of warning signs (sec. 58).

Section 65.—Side Road Sign (W-7, W-8)

The Side Road sign, showing a side-road symbol, either left or right, and at an angle of either 90 or 45 degrees, shall be used in advance of a side-road intersection according to the same warrants and specifications as set forth for the Cross Road sign (W-6, sec. 64).

The 90-degree symbol (W-7) need not be made in rights and lefts, since a single design may be turned to show the intersecting road on either side. The 45-degree symbol, in rights (W-8-R) and lefts (W-8-L), may be mounted erect or inverted to indicate any oblique intersection with reasonable accuracy.

The relative importance of the intersecting roads should be shown by different widths of line, as indicated in section 64.

Section 66.—T Symbol Sign (W-9)

The T Symbol sign shall be used to warn traffic approaching a T intersection on the road that forms the stem of the T, i. e., where traffic must make a turn either to the right or to the left. The sign shall not be used on an approach where traffic is required to stop before entering the intersection, nor at a T intersection that is channelized by traffic islands, nor, generally, where Junction signs or Turn Markers are present.

The relative importance of the intersecting roads should be shown by different widths of line, as indicated in section 64.



W-7
24" x 24"



W-8
24" x 24"



W-9
24" x 24"

The T Symbol sign shall be erected not less than 350 feet nor more than 500 feet in advance of the intersection, and in accordance with the general specifications for the placement of warning signs (sec. 58). It may be desirable to place an additional T Symbol sign at the head of the T directly in line with approaching traffic.

Section 67.—Y Symbol Sign (W-10)

The Y Symbol sign shall be used to warn motorists approaching a Y intersection on the road that forms the stem of the Y. It shall not be used at a Y intersection that is channelized by traffic islands, nor, generally, where Junction signs or Turn Markers are present.

The relative importance of the intersecting roads should be shown by different widths of line, as indicated in section 64.

The Y Symbol sign shall be erected not less than 350 feet nor more than 500 feet in advance of the intersection, and in accordance with the general specifications for the placement of warning signs (sec. 58). It may be desirable to erect an additional Y intersection sign at the fork of the Y directly in line with approaching traffic.



W-10
24'' x 24''

Section 68—Large Arrow Sign (W-11, W-12)

A Large Arrow sign is particularly useful at night to give notice of a sharp change of alignment. It shall be used on all curves where the curvature is 28 degrees or over, and on all curves having a curvature of from 15 to 27 degrees where the central angle exceeds 45 degrees (see fig. 7 for a method of measuring curvature). The sign may also be used at lesser curves if, during a 1-year period, there have been reported three or more personal-injury accidents of a type attributable to failure of the driver to negotiate the curve. It may also, in a single- or double-arrow design, be used at T or Y intersections that have proved hazardous. The sign shall not be used to mark the ends of median strips, center piers, etc., where there is no change in the direction of travel.

The Large Arrow sign shall be 40 inches by 20 inches in size, having a large arrow pointing to right or left (W-11) or to both right and left (W-12). As a warning sign, it should preferably have a yellow background, with symbol in black. Since the sign is designed primarily as a nighttime warning device, however, it is permissible to use a white reflectorized arrow on a black background, if desired, or a black arrow on a re-



W-11
40'' x 20''



W-12
40'' x 20''

flectorized white background. The sign shall in all cases be effectively reflectorized.

The Large Arrow sign shall be erected on the outside of a curve or on the far side of an intersection, in line with, and at right angles to, approaching traffic. It shall be mounted high enough to be visible for at least 500 feet in advance of the sign. No exact specifications can be given for the placement of this sign. Its location must be checked by trial runs over the road by day and by night.

Section 69.—Stop Ahead Sign (W-13)

The STOP AHEAD sign shall be used in advance of a Stop sign (R-1, sec. 28) that is not visible for a sufficient distance to permit the driver to bring his vehicle to a stop at the Stop sign. Obstruction of view due to horizontal or vertical curves, parked vehicles, or foliage, and high approach speeds, should be considered in determining the need for the erection of this sign. In some cases it may be used for emphasis where there is poor observance of the Stop sign.

The Stop Ahead sign shall be erected not less than 350 feet nor more than 500 feet in advance of the Stop sign, and in accordance with the general specifications for the placement of warning signs (sec. 58). In cities it may be necessary to erect the sign less than 350 feet in advance of the Stop sign in order to have it within the same block.

Section 70.—Signals Ahead Sign (W-14)

The SIGNALS AHEAD sign shall be used at any rural signalized intersection where the signal is not visible for a distance of 400 feet in advance of the intersection, or at any signalized intersection where the prevailing approach speeds or conditions of visibility are such as to justify an advance warning.

Use of this sign is warranted where horizontal or vertical curves limit the sight distance on the approach to traffic signals, or where lights or illuminated signs at the intersection may distract the driver's attention from the signal.

The sign shall be erected not less than 400 feet nor more than 600 feet in advance of the intersection, and in accordance with the general specifications for the placement of warning signs (sec. 58). In cities it may be necessary to erect the sign less than 400 feet from the signal, in order to have it within the same block.

Section 71.—Hill Sign (W-15)

The HILL sign shall be used only in advance



W-13
24" x 24"



W-14
24" x 24"

of down grades of 6 percent or more for lengths given in the following table, or grades of 6 percent or more where any part of the grade is on a curve sharper than 4 degrees. Generally, a Hill sign is warranted on descending grades under the following conditions:

- On a 6-percent grade more than 2,000 feet long;
- On a 7-percent grade more than 1,000 feet long;
- On an 8-percent grade more than 750 feet long;
- On a 9-percent grade more than 500 feet long;
- On an 11-percent grade more than 400 feet long;
- On a 13-percent grade more than 300 feet long;
- On a 15-percent grade more than 200 feet long;
- On a grade of 16 percent or more, of any length.

Where safety demands a descent of the grade in intermediate or low gear, the Oversize Hill sign (W-115), 48 inches by 48 inches in size, reflectorized, with a secondary message USE SECOND GEAR, USE LOW GEAR, TRUCKS USE LOWER GEARS, or similar warning, may be used.

The Hill sign or Oversize Hill sign shall be located not less than 300 feet nor more than 500 feet in advance of the beginning of that part of the down grade where conditions require a reduction of speed for safety. It shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58).



W-15
24" x 24"

Section 72.—Bump Sign (W-16)

The BUMP sign shall be used to give warning of a sharp rise in the profile of the road that is sufficiently abrupt to create a hazardous condition, to cause considerable discomfort to passengers, to cause a shifting of the cargo, or to deflect a vehicle from its true course when crossed at speeds 25 percent greater than the normal driving speed for that section of road.

The Bump sign shall be located not less than 300 feet nor more than 500 feet in advance of the hazard, and shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58).



W-16
24" x 24"

Section 73.—Dip Sign (W-17)

The DIP sign shall be used to give warning of any sharp depression in profile that is sufficiently abrupt to create hazards of the type described in connection with the Bump sign (W-16, sec. 72). The Dip sign shall be applicable and used in the same manner as the Bump sign.

The use of the Dip sign at a short stretch of depressed alinement that may momentarily hide a



W-17
24" x 24"

vehicle is not recommended. Such a condition should be treated as a no-passing zone (secs. 39, 40, 134-136).

Section 74.—Narrow Road Sign (W-18)

The **NARROW ROAD** sign shall be used on two-lane roads where the pavement width is reduced abruptly to a width such that two cars cannot pass safely without reducing speed. It is not warranted on minor roads carrying a low volume of traffic, even though the narrowed pavement is only from 16 to 18 feet in width, but the approach to a reduction in pavement width below 16 feet should always be marked.

The Narrow Road sign shall be erected not less than 300 feet nor more than 500 feet in advance of the beginning of the narrow road, and in accordance with the general specifications for the placement of warning signs (sec. 58).



W-18
24" x 24"

Section 75.—Pavement Narrows Sign (W-19)

The **PAVEMENT NARROWS** sign shall be used to give advance notice of a reduction in the number of lanes of pavement, as from three lanes to two lanes, or from four lanes to two lanes. Pavement markings and reflector markers shall also be used to mark such transitions, as described in part II of this manual (secs. 138, 157).

Because wide roadways invite higher speeds, and because of the length of the message, the Pavement Narrows sign shall be 30 inches by 30 inches in minimum size. It shall always be reflectorized.

On divided highways, where the width of the median island will permit, two such signs shall be erected facing approaching traffic, one on the right side and the other on the median island. The sign or signs shall be located not less than 350 feet nor more than 550 feet in advance of the point where the reduction in width begins, and shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 76.—Divided Highway Ahead Sign (W-20)

The **DIVIDED HIGHWAY AHEAD** sign shall be used on the approaches to a section of highway where the opposing flows of traffic are separated by a median island. Because of the length of its message it shall be 30 inches by 30 inches in size. It shall be located not less than 300 feet nor more than 500 feet in advance of the



W-19
30" x 30"



W-20
30" x 30"

dividing island, and in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 77.—Divided Highway Ends Sign (W-21)

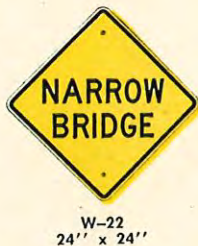
The **DIVIDED HIGHWAY ENDS** sign shall be used at the end of a section of divided highway as a warning of two-way traffic ahead. Because a divided highway invites high speed and because of the length of the message, the Divided Highway Ends sign shall be 30 inches by 30 inches in minimum size. It shall always be reflectorized. The sign shall be located not less than 350 feet nor more than 550 feet in advance of the end of the median island, and shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58).



Section 78.—Narrow Bridge Sign (W-22)

The **NARROW BRIDGE** sign shall be used to indicate a bridge having a clear roadway width of 16 to 18 feet, inclusive, or any bridge having a roadway clearance less than the width of the approach pavement. Additional protection may be provided by the use of reflector markers described in part II of this manual (sec. 156).

The Narrow Bridge sign shall be erected not less than 300 feet nor more than 500 feet in advance of the structure, and in accordance with the general specifications for the placement of warning signs (sec. 58).



Section 79.—One Lane Bridge Sign (W-23)

The **ONE LANE BRIDGE** sign shall be used to mark all bridges having a clear roadway width of less than 16 feet. It may also be used on bridges having roadway widths of less than 18 feet, when commercial vehicles constitute a high proportion of the traffic using the structure or when the alinement approaching the structure is poor. The sign shall be reflectorized, except where the condition or alinement of the approach road is such as to require slow speed. Additional protection may be provided by the erection of reflector markers described in part II of this manual (sec. 156).

The One Lane Bridge sign shall be erected not less than 300 feet nor more than 500 feet in advance of the structure, and in accordance with the general specifications for the placement of warning signs (sec. 58).



Section 80.—Low Clearance Sign (W-24)



W-24
30" x 30"

The LOW CLEARANCE sign, indicating low overhead clearance and showing the exact amount of clearance at low bridges, underpasses, and other overhead structures, shall be used at all points where clearance is less than 6 inches greater than the maximum height of vehicle and load permitted under the State law, and, in any case, where the clearance is less than 13 feet. The actual clearance shall be shown on the sign, to the nearest inch.

Act V of the Uniform Vehicle Code (sec. 172) sets a maximum height of $12\frac{1}{2}$ feet for vehicle and load. Hence any clearance less than 13 feet should be marked, regardless of State law.

The Low Clearance sign shall be 30 inches by 30 inches in size, to accommodate the relatively long message required. Because low clearances are not always apparent, especially at night, it is essential that the sign be reflectorized on all but the least important roads. Additional protection should be provided by markings as specified in part II of this manual (secs. 151, 156).

In rural districts the sign shall be erected not less than 350 nor more than 500 feet in advance of the impaired clearance, and in accordance with the general specifications for the placement of warning signs (sec. 58). In urban districts it should ordinarily be located nearer to the point of hazard.

In the case of an arch or other structure under which the clearance varies greatly, two or more signs should be used as necessary on the structure itself to give accurate information as to the practical clearance over the entire roadway.

Section 81.—Pavement Ends Sign (W-25)



W-25
24" x 24"

The PAVEMENT ENDS sign shall be used where a pavement surface changes from a hard-surfaced pavement to a low-type surface or an earth road.

It shall be erected not less than 300 feet nor more than 500 feet in advance of the beginning of the lower-type surface, and in accordance with the general specifications for the placement of warning signs (sec. 58).

Section 82.—Men Working Sign (W-26)

The MEN WORKING sign shall be used primarily for the protection of men working on the road in the path of traffic, or for the protection of traffic when the nature of the work itself is such as to create a hazard.

Men Working signs shall be placed approxi-

mately 350 feet on each side of the section where men are at work. The signs shall be mounted on substantial portable supports, not easily knocked over or blown down, and placed in the center of the road unless the width of pavement, poor shoulders, or other conditions make this inadvisable, in which case they shall be placed adjacent to the roadway on the shoulder of the road. They shall be in place as long as there are men working on the road, or there is any piece of equipment in the roadway, etc., but shall not be left up during the lunch period or at night or on holidays if the road is free from hazard at that time. An 18- by 18-inch red flag should be displayed above each sign, and if used at night a red lantern or bomb torch should be placed beside it. The signs should be moved forward as any work progresses so that there is at no time a distance of more than 1,000 feet between the sign and the workmen.



Section 83.—Fresh Oil Sign (W-27)

The **FRESH OIL** (or **FRESH TAR**) sign shall be used to warn traffic of resurfacing operations that render the surface of the pavement temporarily hazardous, and that may cause objectionable splashing on vehicles. This sign, like the Men Working sign, is intended for temporary use on portable mountings.



The sign shall be erected on the right-hand side of the road, or on a portable support in the center of the roadway if the width permits. It should be located not less than 300 feet nor more than 500 feet in advance of the section being treated.

Section 84.—Soft Shoulders Sign (W-28)

The **SOFT SHOULDERS** sign shall be used where soft shoulders present a hazard to vehicles that may get off the pavement. This sign will usually be warranted on newly seeded shoulders or on roadways where shoulders are dangerously soft due to weather conditions. The sign should be removed when the hazard no longer exists.

Soft Shoulder signs shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58). One sign shall be placed at or near the beginning of the soft shoulder condition, and other signs shall be placed at intervals throughout the length of the road where the condition exists.



Section 85.—Slippery When Wet Sign (W-29)

The **SLIPPERY WHEN WET** sign shall be used to warn traffic of an extraordinarily slippery condition when the pavement is wet. The use of this sign should be kept to an absolute minimum, and upon correction of the slippery condition the sign should be removed.

The sign shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58). On rural highways it should be located 500 feet in advance of the beginning of the slippery section and at not greater than 2-mile intervals on long sections of such pavement. In urban districts these distances should be greatly reduced.



W-29
24" x 24"

Section 86.—Double Arrow Sign (W-30)

The **Double Arrow** sign showing a double-headed horizontal arrow shall be used at loading and refuge islands, traffic islands with curbs more than 3 inches high, and obstructions in the roadway, where traffic is permitted to pass on either side of the island or obstruction.

The sign should normally be mounted at a height of 2½ feet to the bottom of the sign. On an island it should be mounted at the approach end or as close thereto as practicable. It should be mounted on the face of, or just in front of a pier or other large obstruction, in which case the standard stripe markings on the obstruction (sec. 151) should be discontinued to leave a 3-inch space around the outside of the sign.

Because an obstruction in the line of traffic is likely to be obscured by vehicles, a second sign of the same design should ordinarily be mounted directly above the standard sign, with its lowest edge 7 feet above the pavement.

Where traffic must keep to the right of the island or other obstruction, the **Keep Right** regulatory sign (R-14, sec. 42) should be used.

Section 87.—School Sign (W-31)

The **SCHOOL** sign shall be used only at locations where school buildings or grounds are adjacent to the highway and where passing traffic creates a hazard. It shall remain in place during the school season and be removed at the end of the school year, except where the school ground is used throughout the summer as a playground.

This sign should be erected not to exceed 500 feet in advance of the school grounds or of the crossing used by pupils, in accordance with the



W-31
24" x 24"

general specifications for the placement of warning signs (sec. 58).

In some locations where the hazard is particularly great it may be desirable to use a portable sign set up in, or immediately adjacent to, the roadway. **Such a sign shall be displayed only during the hazardous hours and shall be removed at all times when the presence of pupils does not require its use.**

As an alternative to the portable sign, a sign on a fixed mounting may be designed with a hinge or other means for turning or folding it out of sight and locking it in functioning or nonfunctioning position.

Ordinarily the School sign need not be reflectorized but if there is any considerable use made of the school building at night it may be desirable to give the sign adequate nighttime visibility.

Section 88.—Railroad Advance Warning Sign (W-32)

Because railroad grade crossings present a special type of extreme hazard, warning signs of distinctive designs are prescribed for them (figs. 6, 18).

The Railroad Advance Warning sign shall be a yellow disk 30 inches in diameter, carrying a 90-degree crossbuck X and the letters RR in black. Every Railroad Advance Warning sign shall be reflectorized.

The sign shall be used in advance of every railroad crossing, even if protected by signals, gates, or flagmen, except in the following instances:

1. At a minor siding or spur which is infrequently used and which is guarded when in use by a member of the train crew.
2. In the business districts of large cities where the crossings are fully protected and the physical conditions are such that even a partially effective display of the sign is impossible.

In rural districts this sign shall normally be placed 500 feet in advance of the crossing, although local conditions, such as grades, curves, and limited visibility, may make some intermediate distance between 300 feet and 500 feet more satisfactory. In any case the distance shall be great enough to permit vehicles at prevailing speeds to be brought to a complete stop before the crossing is reached. The sign shall be erected on the right-hand side of the roadway in accordance with the general specifications for the placement of warning signs (sec. 58).



W-32
30" diameter

In residence or business districts where low speeds are prevalent, the sign may be placed a minimum distance of 100 feet from the crossing. If there is a street intersection within 100 feet, an additional sign or signs should be so placed as to warn traffic approaching the crossing from each intersected street.

Railroad Advance Warning signs are usually off the railroad right-of-way and are properly the responsibility of the highway authorities.

Section 89.—Railroad Crossbuck Sign (W-33)

The design of the commonly used Railroad Crossbuck, with auxiliary sign showing the number of tracks, has been standardized by the Joint Committee on Grade Crossing Protection of the Association of American Railroads. The crossbuck sign is furnished and installed by the railroad company, and is usually located on the railroad right-of-way to show the location of the tracks and the number of tracks.

Details are shown in *Railroad Highway Grade Crossing Protection*, Bulletin No. 3 (or subsequent issue), Association of American Railroads, Joint Committee on Grade Crossing Protection. It should be noted, however, that the bulletin shows certain crossbucks without reflectorization, whereas this manual specifies that all warning signs shall be reflectorized.

The crossbuck shall be white with the words **RAILROAD CROSSING** in black lettering. If there are two or more tracks, including sidings, the number of tracks shall be indicated on an auxiliary sign of inverted T shape mounted below the crossbuck. The distance that should be assumed to separate tracks before an additional crossing sign is considered necessary is 100 feet, unless local conditions require otherwise.

The practice in some localities of placing the Railroad Crossbuck sign on a pedestal or island in the center of the roadway is strongly disapproved. The sign shall be erected on the right-hand side of the roadway on each approach to the crossing, not more than 15 feet from the center line of the nearest track, and not less than 6 feet nor more than 10 feet from the edge of the pavement. The height should be 10 feet above the level of the highway to the center of the crossbuck, but this may be varied as required by local conditions.

Section 90.—Crossing Signs (W-34)

The Crossing sign, indicating various types of crossings, as **SCHOOL CROSSING**, **TRUCK CROSSING**, **PEDESTRIAN CROSSING**, **CAT-**



TLE CROSSING, DEER CROSSING, shall be used at hazardous crossings of the types indicated. The signs may or may not be of a temporary or seasonal nature, but should be removed if and when the hazardous conditions are terminated.

In rural areas the sign shall be located not less than 300 feet nor more than 500 feet from the crossing. In urban areas a shorter distance will usually be desirable. The sign shall be erected in accordance with the general specifications for the placement of warning signs (sec. 58). In many instances it may be desirable to define the crossing by pavement markings, as prescribed for cross walks in part II of this manual (sec. 144).



W-34
24" x 24"

Section 91.—Advisory Speed Sign (W-35)

The Advisory Speed sign is a small plate 13 inches by 13 inches square, with the message "(35) M. P. H." in black on a yellow background. It may be used in conjunction with any standard yellow warning sign to indicate the maximum safe speed around a curve or through a hazardous location (fig. 1). When used, it shall be mounted immediately below the standard warning sign, and on the same post, with its lower edge not less than 2 feet above the crown of the roadway. The speed shown shall be in multiples of 5 miles. In no case shall such a sign be erected until the safe speed has been determined by accepted traffic engineering procedures and officially approved. Because changes in surface characteristics, sight distance, etc., may alter the safe speed, each location should be periodically rechecked and the speed sign corrected if necessary.



W-35
13" x 13"

Section 92.—Other Warning Signs

Warning signs other than those specified above may be required under special conditions. They should in every case conform with the general specifications for shape, color, and placement of warning signs as set forth in sections 57 and 58.

Typical miscellaneous warning signs are **PLAYGROUND, BRIDLE PATH, HOSPITAL, CROSS WALK, TUNNEL, DRAW BRIDGE, UNEVEN TRACKS, ROUGH ROAD, HIGH WATER, RANGE CATTLE, (FACTORY) ENTRANCE, and SLIDES.** The applications of such signs are sufficiently apparent as to require no detailed specifications.

D—GUIDE SIGNS

Section 93.—Application of Guide Signs

Guide signs are essential to guide the motorist along established routes, to inform him of intersecting routes, to direct him to city or village destinations, to identify nearby rivers and streams, parks, forests, and historical sites, and generally to give him such informa-

tion as will help him along his way in the most simple, direct method possible.

Guide signs are here considered in three major groups:

1. Route markers and auxiliary markers (secs. 95-112).
2. Destination and distance signs (secs. 113-116).
3. Information signs (sec. 117).

Unlike other types of signs, guide signs do not lose effectiveness by frequent use. When there is any doubt as to the advisability of any such sign, it should be erected.

Section 94.—Design of Guide Signs

All Route Markers and auxiliary markers used therewith shall be designed with a white background on which the lettering or symbols and border shall be black. Destination, Distance, and Information signs shall be black on white, or, optionally for enlarged or oversize signs, white on black.

Recent studies by the Public Roads Administration and the Ohio State Department of Highways have shown that white lettering on a black background yields better legibility than the hitherto standard black on white, but that black signs of ordinary dimensions are definitely less conspicuous than white signs in the daytime. The optional white on black has had numerous advocates favoring its use in large signs where size alone gives sufficient assurance of conspicuous visibility. To improve daylight visibility, a relatively wide white border is recommended.

Except for Route Markers, which are of special shapes as specified hereafter (secs. 96, 97) all guide signs are rectangular, with the longer dimension horizontal.

Route Markers and Destination signs at important intersections shall be reflectorized or illuminated. Other guide signs may advantageously be reflectorized or illuminated and any doubt should always be resolved in favor of reflectorizing or illuminating.

Section 95.—Route Markers and Auxiliary Markers

Route Markers are important to identify numbered highway routes, but to accomplish their purpose they must be supplemented by various types of auxiliary markers and signs to indicate junctions, turns, and directions thereof as well as temporary, alternate, by-pass, and business routes and detours. Except where used as Confirming or as Reassurance Markers as hereinafter described (sec. 98), Route Markers are always mounted in conjunction with auxiliary signs to form Junction assemblies, Route Turn assemblies, or Directional Marking assemblies.

U S Route Markers shall be displayed only on the U S numbered highway system or the approaches thereto. Similarly, State Route Markers shall be used only on State numbered routes and their approaches.

Section 96.—Design of Route Markers (M-1, M-2)

The U S Route Marker (M-1) shall consist of a shield-shaped plate 16½ inches by 16 inches in size, carrying the State name, the letters "U S" and the route number. The sign shall have a white background with black lettering. State Route Markers (M-2) are

of special design, as determined by each State. They should be of approximately the same size as U S markers.



M-1
16½" x 16"



M-101
24" x 24"

Section 97.—Oversize Route Markers (M-101, M-102)

The Oversize Route Marker shall be a square sign 24 inches in size. For U S routes it shall carry only the route number, in large numerals, within the enlarged outline of the U S shield (M-101). For State numbered routes the design should incorporate some distinguishing outline from the State Route Marker, if possible, or other identifying character (M-102).

The symbol and numerals shall be black on a white background. The usual black border around the edge of the plate is omitted to emphasize the symbol.

The Oversize Route Marker should ordinarily be used only at rural intersections of two major routes, as defined in section 24, or occasionally at intersections in residence or business districts where special emphasis is needed. It may also be used as a Confirming Marker (sec. 98) just beyond such intersections. All auxiliary markers used with Oversize Route Markers (except Temporary, Alternate, By-pass, and Business Route, Detour, and Cardinal Direction Markers) shall also be of oversize design.

The Oversize Route Marker shall be located and erected according to the specifications set forth for the standard Route Marker.

Section 98.—Confirming and Reassurance Markers

Confirming Route Markers, without auxiliary Junction, Turn, or Directional Markers, shall be erected just beyond all intersections where there is any possibility that the motorist might lose the route. In rural districts they shall be placed not less than 25 feet nor more than 75 feet beyond the far pavement line of the intersected highway. In urban areas these distances shall be 10 feet and 50 feet, respectively.

The application of Confirming Route Markers is illustrated in figures 8, 9, and 10.

Reassurance Markers, also without auxiliary Junction, Turn, or Directional Markers, shall be located between intersections as required, and just outside the built-up area of any incorporated city or town. They shall be located on straight, open stretches of highway at random intervals not to exceed 1½ miles. On winding roads it may be desirable to place them more frequently.

Where two or more routes follow the same road, Route Markers for all the routes shall be erected on the same support. If both U S and State numbered routes are shown, the U S Marker or Markers should be placed at the top of the assembly, or to the left in horizontal assemblies, unless a State route has dominant importance. Subject to the precedence given U S Markers, Route Markers should be

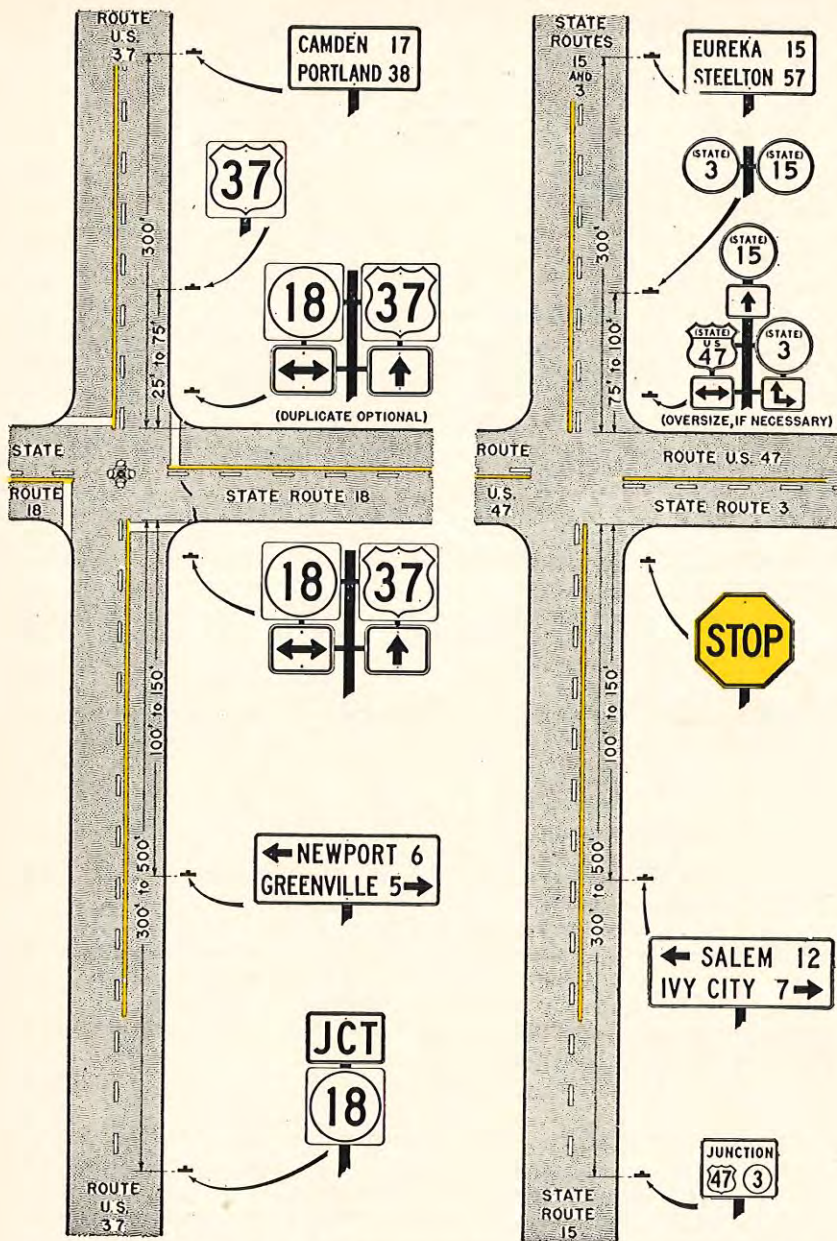


Figure 8.—Typical route markings at intersections (for one direction of travel only).

mounted in numerical order from top to bottom or from left to right.

In rural districts single Route Markers shall be mounted so that the bottom will be $2\frac{1}{2}$ feet above the crown of the roadway. In a group the bottom of the lowest marker shall not be less than 2 feet above the crown of the roadway. On ascending or descending grades these heights may be varied so that headlights will properly illuminate the marker or markers by night. Where parked vehicles or other obstructions may interfere with visibility, mounting heights should be as specified for urban locations. The marker or markers shall be set not less than 6 feet nor more than 10 feet from the edge of the roadway, except on narrow or unimproved roads where this lateral spacing may be reduced (fig. 2).

In residence districts Route Markers, of either confirming or reassurance type, shall be spaced not more than two blocks apart, and in any case, so frequently that there is always at least one marker visible ahead along the route. The best location is immediately beyond the intersected street, to "pull" the motorists through the intersection. The markers shall be mounted so that the bottom of the marker or marker assembly is not less than 7 feet above the top of the curb. The left-hand edge of the marker or assembly shall be not less than 1 foot back from the edge of the curb. In locating markers, particular care should be taken so that they will not be obscured by parked cars, posts, trees, or other objects; and if they are not reflectorized they should, if possible, be so located that they can be illuminated by street lights.

In business districts the proper location of Route Markers is extremely important because it is very easy for the motorist to become confused and lose his route. Extreme care should be taken to erect the markers where they can be seen easily. Markers should be located on the far side of every street intersection on a numbered route, or so that at all times a Route Marker is plainly visible ahead. They shall be mounted so that the bottom of the marker or assembly shall be not less than 7 feet above the curb, and the left-hand edge at least 1 foot back from the curb.

Section 99.—Junction Sign (M-3)

The Junction sign shall be a horizontal rectangle $16\frac{1}{2}$ inches by 8 inches in size, carrying the abbreviation JCT in black letters on a white background. It shall be mounted immediately above a Route Marker (M-1, M-2), thus making a Junction assembly.

A Junction assembly shall be erected in advance of every intersection where a marked route is intersected or joined by another marked route. The Route Marker in the assembly shall carry the number of the intersected or joined route. Where two or more routes are to be indicated, a separate Junction assembly shall be used for each route and all assemblies mounted on one post. Two assemblies should preferably be mounted side by side rather than one above the other.

Where there are several assemblies they should



M-3
 $16\frac{1}{2}'' \times 8''$
 M-103
 $24'' \times 16''$

be arranged, so far as practicable, in the following manner:

1. The assembly for a route intersecting from the left should be to the left of a horizontal grouping, or in the middle of a vertical grouping.
2. The assembly for a route intersecting from both left and right, or for a route proceeding only straight ahead out of the intersection, should be at the top of a vertical grouping, or in the middle of a horizontal grouping.
3. The assembly for a route intersecting from the right should be to the right of a horizontal grouping, or at the bottom of a vertical grouping.

This arrangement is similar to that prescribed for the corresponding Directional Marking assemblies at the intersection (sec. 104).

In rural districts the Junction assembly shall be erected not less than 300 feet nor more than 500 feet in advance of the intersection, on the right-hand side of the roadway and facing approaching traffic. The assembly thus serves as an intersection warning as well as a guide sign. It shall normally be erected so that the lowermost part of the assembly will not be less than 2½ feet above the crown of the roadway, or, if several assemblies are grouped vertically the lowermost part shall not be less than 2 feet above the roadway crown. Where parked vehicles or other obstructions may interfere with visibility, the height should be as specified for urban locations. The assembly or group of assemblies shall be not less than 6 feet nor more than 10 feet from the edge of the roadway, except where shoulder width requires closer mounting (fig. 2).

In residence districts the Junction assembly shall be erected midway in the block preceding the intersection, but in no case farther than 200 feet from the center of the intersected street. It shall be erected so that the lowermost part of the assembly or group will be not less than 7 feet above the top of the curb. The nearest part of the assembly shall be not less than 1 foot back from the curb edge.

In business districts the Junction assembly shall be erected as in residence districts.

Figures 8, 9, and 10 show typical applications of Junction assemblies.

Section 100.—Oversize Junction Sign (M-103)

The Oversize Junction sign, 24 inches by 16 inches in size, shall carry the abbreviation JCT in black letters on a white background. It shall be used in conjunction with an Oversize Route Marker (sec. 97) on a major route, as defined in section 24, in advance of its junction

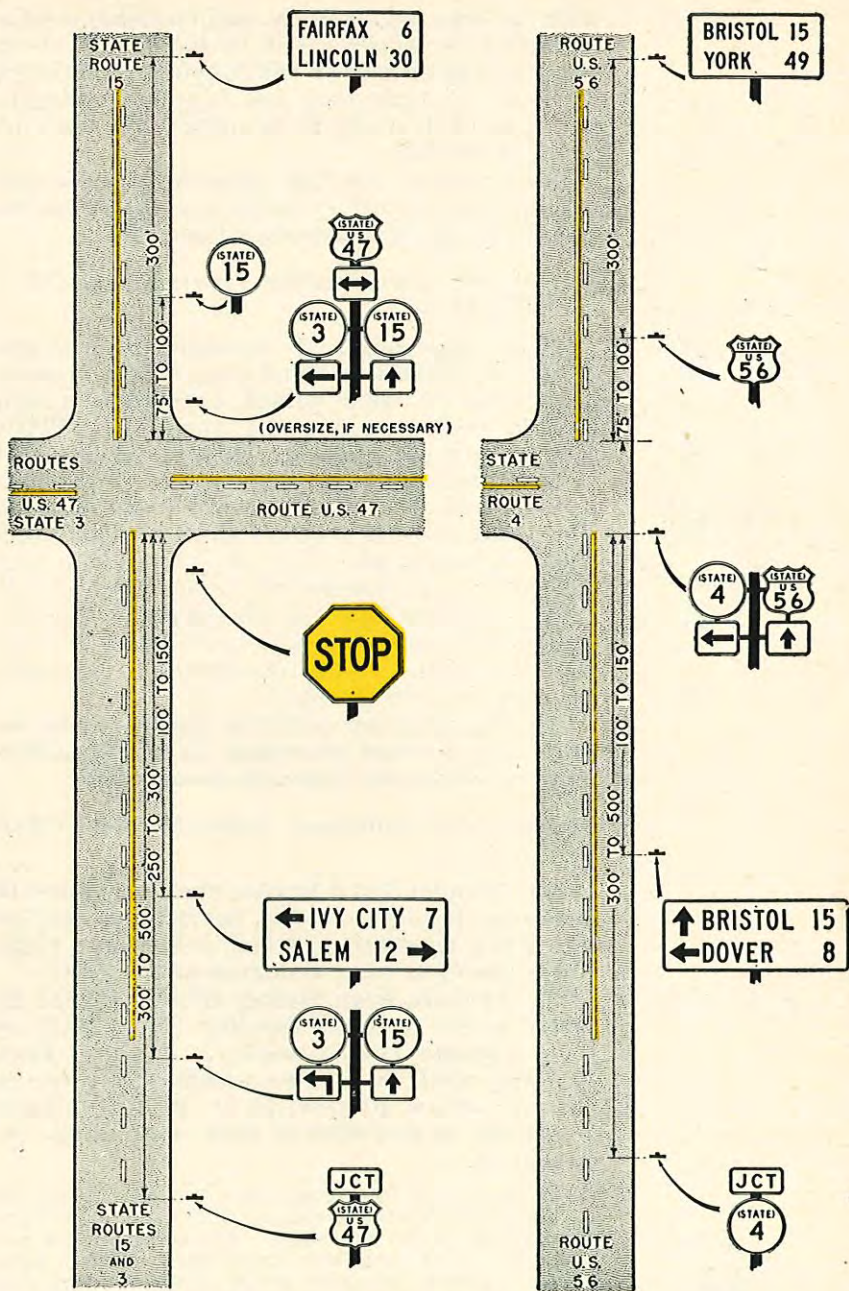


Figure 9.—Typical route markings at intersections (for one direction of travel only).

with another major route, and on minor routes at their intersections with major routes where physical conditions or the accident experience warrant. If more than one Junction assembly is required in a single mounting all shall be of the same size.

The Oversize Junction sign shall be located and erected according to the specifications for the standard Junction sign (sec. 99).

Section 101.—Combination Junction Sign (M-4, M-5, M-6)

As an alternative to standard or oversize Junction assemblies where more than one route is to be intersected or joined, a rectangular sign may be used carrying the word JUNCTION above the route numbers, each of which shall be identified as a U S or State route by an outline symbol as in the Oversize Route Marker. The numerals and symbols shall be black on a white background. The size of the sign will depend on the number of routes involved. It should be noted that the Combination Junction sign must be individually designed for each intersection, whereas the Junction assemblies use standard signs from stock (fig. 8).

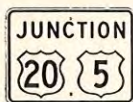
The Combination Junction sign shall be located and erected according to the specifications set forth for Junction assemblies.

Section 102.—Advance Turn Marker (M-7, M-8)

The Advance Turn Marker shall be a plate 13 inches by 10 inches in size, carrying a right or left arrow the shaft of which is bent at a right angle (M-7) or at a 45-degree angle (M-8).

The Advance Turn Marker shall be placed directly under a Route Marker (M-1, M-2) to form a Route Turn assembly. A Route Turn assembly shall be used on a numbered route in advance of an intersection to indicate a turn or change in direction of that route at the intersection.

The bent-arrow design supersedes the former standard Advance Turn Marker having an R or an L to indicate the direction of the turn ahead. The revised design has the advantage of using clear directional symbols in place of the somewhat confusing letters of the old standard. The bent arrow, furthermore, indicates that the turn is to be made at a point a short distance ahead, thus avoiding the misunderstanding that frequently arises from the use of a straight horizontal arrow as an Advance Turn Marker. The horizontal arrow should be, and is, reserved for use only at the actual point where the turn is to be made.



M-4
24" x 18"



M-7
13" x 10"
M-107
19 1/2" x 15"

If several routes turn at an intersection, each shall be marked with a separate Route Turn assembly, whether they turn in the same or in different directions. Where one or more routes turn while one or more proceed straight through, the routes that turn shall be marked with Route Turn assemblies, using the appropriate right or left Advance Turn markers, while the straight-through routes may be indicated by a similar assembly, using the vertical Directional Marker arrow (M-11).

Route Turn assemblies for all routes shall be mounted on one post, preferably in a horizontal arrangement. Where there are routes turning in opposite directions, Route Turn assemblies for routes turning left shall be mounted to the left of the group of assemblies, and those for right-turning routes to the right. If straight-through assemblies are used, the right- and left-turn assemblies shall be to the right and left of them, respectively. In a vertical arrangement of assemblies the straight-through assemblies shall be at the top, followed by left- and right-turn assemblies, respectively. Where two or more routes turn in the same direction, the assembly for a U S route should be above or to the left of that for a State route. If the number of turning routes makes it necessary to use a combination horizontal and vertical arrangement, the above rules can be followed in principle.

Figures 9 and 10 show typical applications of Route Turn assemblies.

Advance Turn Markers may be omitted where the character of the roadway clearly indicates the course of the route or routes.

In rural districts the Route Turn assembly shall be erected not less than 250 nor more than 300 feet in advance of the turn, facing traffic approaching the intersection. Height and lateral placement shall be the same as for Junction assemblies (sec. 99).

In residence and business districts the Route Turn assembly shall be erected not more than 250 feet in advance of the turn. It is suggested that in congested districts the assemblies be duplicated, spaced from 50 to 100 feet apart. The assemblies should be located so that they will not turn traffic into an alley or secondary street in advance of the proper turn. Height and lateral placement of Route Turn assemblies shall be the same as for Junction assemblies (sec. 99).



M-8
13' x 10'
M-108
19½' x 15'

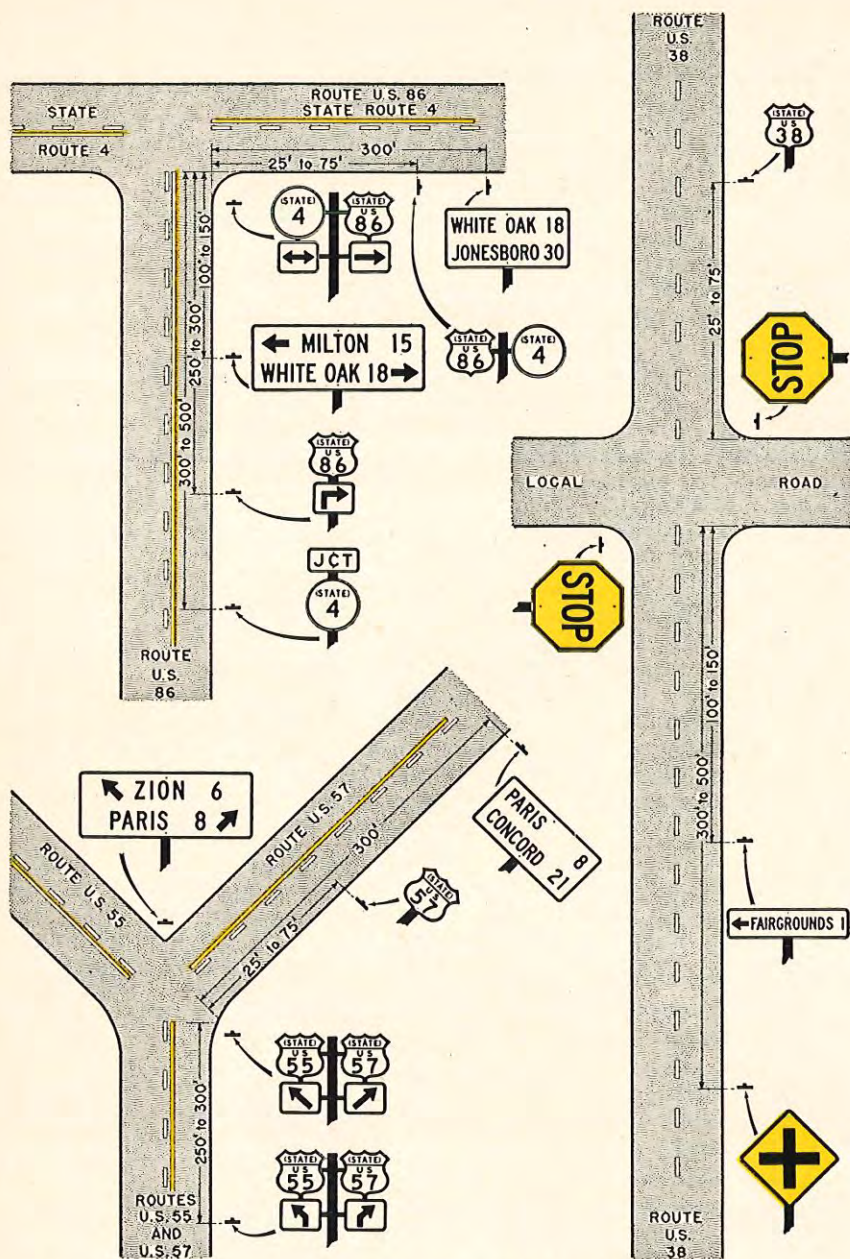


Figure 10.—Typical route markings at intersections (for one direction of travel only).

Section 103.—Oversize Turn Marker (M-107, M-108)

Oversize Turn Markers, 19½ inches by 15 inches in size, shall be used with Oversize Route Markers (sec. 97) on a major route, as defined in section 24, where extra emphasis is required, or at any intersection where the Oversize Junction sign (sec. 100) is used. The arrows shall be similar to those in the regular Advance Turn Markers, in black on a white background.

The Oversize Turn Marker shall be located and erected according to the specifications for the regular Advance Turn Marker. If more than one Advance Turn Marker is required in a single mounting, all shall be of the same size.

Section 104.—Directional Marker (M-9 to M-14, inclusive)

The Directional Marker shall be a horizontal rectangular plate 13 inches by 10 inches in size, carrying a single arrow pointing horizontally to right or left (M-9), diagonally upward to right or left (M-10), or vertically (M-11); a double horizontal arrow (M-12); or an L-shaped double arrow pointing both vertically and to right or left, either horizontally (M-13) or slanting upward (M-14). The arrows shall be black on a white background.

A Directional Marker shall be mounted directly below a Route Marker (M-1, M-2) to form a Directional Marking assembly, used at intersections to show the direction of a route turn or the direction or directions of an intersected route.

A Directional Marking assembly displaying the number of the turning route shall be used to confirm a turn or change in direction of a route at an intersection (indicated in advance by a Route Turn assembly, as prescribed in section 102). A separate Directional Marking assembly shall be used for each turning route. Only the single arrow (M-9, M-10) pointed in the direction of the turn can be used in such an assembly (figs. 9, 10). Where one or more routes turn or are intersected and one or more routes continue straight ahead, it is generally desirable to mark the straight-through route by a Directional Marking assembly using the vertical arrow (M-11).

A Directional Marking assembly with vertical arrow, however, should not be used at any inter-



M-9
13" x 10"
M-109
19½" x 15"



M-10
13" x 10"
M-110
19½" x 15"



M-11
13" x 10"
M-111
19½" x 15"



M-12
13" x 10"
M-112
19½" x 15"



M-13
13" x 10"
M-113
19½" x 15"



M-14
13" x 10"
M-114
19½" x 15"

section alone, in the absence of other assemblies indicating right or left turns. The Confirming Marker just beyond the intersection (sec. 98) provides adequate marking for a route passing straight through, where there are no turning or intersected routes.

A Directional Marking assembly, with the number of the intersected route and proper arrow, shall also be used to confirm a junction of two or more numbered routes (indicated in advance by a Junction assembly as prescribed in section 99), and to indicate the direction or directions of the intersected route (figs. 8-10). When two or more numbered routes are intersected, a separate Directional Marking assembly shall be used to mark each route.

When an intersected route begins or terminates at the intersection, the single-arrow Directional Marker (M-9, M-10) shall be used (fig. 9). A route crossed at the intersection (fig. 8) requires the use of the double-arrow Directional Marker (M-12), and a route that may be followed either by proceeding straight ahead or by turning (fig. 8) shall be indicated by the two-directional arrow (M-13, M-14).

Figures 8, 9, and 10 show typical applications of Directional Markers.

All Directional Marking assemblies, whether for route turns or for intersected routes, facing traffic entering an intersection from a single direction shall be on a single mounting. When more than one route turns or is intersected the assemblies should be arranged in the following order of precedence:

1. In a horizontal grouping the Directional Marker arrows from left to right should be: (a) Left horizontal arrow, (b) left diagonal arrow, (c) left L-shaped double arrow, (d) double horizontal arrow, (e) vertical arrow, (f) right L-shaped double arrow, (g) right diagonal arrow, and (h) right horizontal arrow.

2. In a vertical grouping the vertical arrow should be at the top, followed by the double horizontal arrow, then by the remaining arrows in the same order as for a horizontal arrangement.

When the same direction is displayed for more than one route, the U S Markers, if any, should appear in the most conspicuous position, i. e., to the left or above.

A horizontal arrangement is generally preferable to a vertical, since each Directional Marker is thus more clearly associated with its respective Route Marker. Where there are more than two assemblies, however, it is usually desirable to adopt a combination vertical and horizontal arrangement.

Section 105.—Location of Directional Marking Assemblies

Directional Marking assemblies shall be located on the near right-hand corner of the intersection. At major intersections it is often desirable to install auxiliary markers on the far right-hand corner to confirm the near-side markers.

When a Directional Marking assembly and a Stop sign must be used at the same intersection an exception must be made to the general rule that signs for different purposes should be erected on separate posts, not less than 100 feet apart (sec. 19), or to the requirement that the Directional Marking assembly shall be on the near right-hand corner. The placement of the Stop sign is definitely fixed by the intersection design. Mounting a Directional Marking assembly above a Stop sign, on the same post, has serious disadvantages, particularly in urban areas where the lowest sign must be at least 7 feet above the curb (sec. 17). Placing the Directional Markers on a separate post adjacent to the Stop sign is not practical where space is limited. It may also draw attention away from the Stop sign. If located just in advance of a Stop sign, a Directional Marking assembly may obscure the more important regulatory sign. Furthermore, the guide signs so placed will not be visible to a driver who has properly stopped just short of the Stop sign.

It is more important that guide signs be readable at the right time and place than that they be located with absolute uniformity. When the near-corner position is not practical for Directional Marking assemblies, therefore, as when a Stop sign must occupy that position, a far-side mounting is the preferred alternative for the Directional Markers, with oversize signs if necessary for legibility. If it is found advantageous to place Directional Marking assemblies in advance of the intersection, an additional set of markings should be mounted on the far right-hand corner. The standard near-corner location, however, places the Directional Marking assembly where it can be read at close range, without interference from cross traffic, and it should be held to in the absence of compelling reasons to the contrary.

In rural districts the Directional Marking assembly shall ordinarily be mounted so that its lowermost part is not less than 2½ feet above the crown of the roadway. Where two or more assemblies are mounted vertically, the lowermost part shall not be less than 2 feet above the crown of the roadway. Where there is heavy traffic, or where other obstructions to view may occur, a higher mounting as for residence or business districts may be necessary. The assembly should be located as near to the corner as practicable, not less than 6 feet nor more than 10 feet from the edge of either intersecting roadway (fig. 2).

Care should be taken that groups of Directional Marking assemblies in a single mounting will not block the view in any direction at an intersection.

In residence and business districts the assemblies shall be mounted not less than 7 feet above the top of the curb, and with their nearest edge not less than 1 foot back from either curb. In business districts it may be desirable to mount them on a bracket over the roadway, in which case they shall not be less than 14½ feet above the pavement.

At complex intersections or interchanges, with connecting ramps or

one-way roadways, the effective location of directional markings is often exceedingly difficult to achieve. It may be best under some circumstances to separate the Directional Marking assemblies so that those indicating a turn will be on the near side of the turn and those for straight-ahead traffic on the far side. However, no rules are here prescribed for directional markings at such intersections, as each must be studied independently and the best route marking be worked out by observation and experiment. It must be remembered that at complex interchanges the motorist cannot depend on his sense of direction to tell him whether to turn right or left, and that he is wholly dependent on the signs he reads. It is absolutely necessary, therefore, that the directional markings be clear and unmistakable.

Section 106.—Oversize Directional Marker (M-109 to M-114, inclusive)

Oversize Directional Markers, 19½ inches by 15 inches in size, shall be used with Oversize Route Markers (sec. 97) on a major route, as defined in section 24, where extra emphasis is required; or at any intersection where the Oversize Junction sign (sec. 100) or Oversize Turn marker (sec. 103) is used. The arrows shall be similar to those in the regular Directional Markers, in black on a white background. The Oversize Directional Markers shall be located and erected according to the specifications for the regular Directional Marker. If more than one Directional Marker is required in a single mounting, all shall be of the same size.

Section 107.—Temporary Marker (M-15)

The Temporary Marker shall carry the word **TEMPORARY** in black letters on a white plate 16½ inches by 8 inches in size. It shall be mounted immediately above a Route Marker (M-1, M-2) to indicate either:

1. A route temporarily designated but not intended as a permanent part of a regularly numbered route, or
2. A temporary detour from an established route, due to emergency or major reconstruction.

Where it is planned to relocate a route at a later date, use of the "temporary" designation will often help to avoid future misunderstanding and ill feeling. On the other hand, the use of "temporary" instead of "detour" avoids the suggestion of poor road that is associated in the public mind with the latter term. The temporary route may be another U S or State numbered route, a county or township road, or a city street.

The Temporary Route assemblies shall be used on temporary routes, and shall be located and erected in accordance with the specifications set forth for standard Route Markers. They shall promptly be removed when the temporary route is abandoned.

Section 108.—Alternate Marker (M-16)

The Alternate Marker shall carry the word **ALTERNATE** in black letters on a white plate



M-15
16½" x 8"

16½ inches by 8 inches in size. It shall be mounted immediately above a Route Marker (M-1, M-2) to designate an alternate routing between two points on a numbered route. The Alternate Route assembly shall be used in the same manner as a regular Route Marker, and shall be located and erected in accordance with the same specifications.

The designation of an alternate U S route shall be in accordance with the established policy of the American Association of State Highway Officials, as set forth in the 1946 *Reference Book* of that Association. No alternate U S route may be designated or marked without the approval of the Executive Committee of the Association.

Section 109.—By-pass Marker (M-17)

The By-pass Marker shall carry the word BY-PASS in black letters on a white plate 16½ inches by 8 inches in size. It shall be mounted immediately above a Route Marker (M-1, M-2) to designate a route that branches from the regular numbered route through a city, by-passes the city, and rejoins the regular numbered route beyond the city. The By-pass Route assembly shall be used in the same manner as a regular Route Marker, and shall be located and erected in accordance with the same specifications.

Section 110.—Business Route Marker (M-18)

The Business Route Marker shall carry the word BUSINESS in black letters on a white plate 16½ inches by 8 inches in size. It shall be mounted immediately above a Route Marker (M-1, M-2) to designate an auxiliary route that branches from a regular numbered route through a city to carry traffic through the business portion of the city. The Business Route assembly shall be used in the same manner as a regular Route Marker, and shall be located and erected in accordance with the same specifications.

Section 111.—Detour Marker (M-19, M-20)

The Detour Marker (M-19) shall carry the word DETOUR in black letters on a white plate 16½ inches by 8 inches in size. It shall be mounted immediately above a Route Marker (M-1, M-2) to indicate an emergency routing of traffic due to a temporary closing or blocking of the regularly marked route. Conditions calling for a detour include road reconstruction or major maintenance work, bridge out, high water, or similar circumstances that make the regular route impassable. The Detour assembly should be located and erected in general accordance with the



M-16
16½" x 8"



M-17
16½" x 8"



M-18
16½" x 8"



M-19
16½" x 8"

specifications for regular Route Markers. However, since detours frequently necessitate the use of unimproved or poorly defined roads, there is greater likelihood that motorists following the route may become confused. Extreme care should be exercised to see that Detour assemblies are located and erected as conspicuously as possible and at short intervals as needed.

The use of the Temporary Marker (M-15) in place of the Detour Marker is optional. "Temporary" does not carry the suggestion of inferior roads often associated with the term "detour."

In unforeseen emergencies, when it is necessary to detour traffic, there may be used the standard Detour Marker (M-19) with a Directional Marker (M-9 or M-11) mounted directly beneath it. These markers can be attached to any convenient post or other available support, and should be placed as frequently as necessary to guide traffic along the detour route back to the regularly marked route.

An alternative to this method is the use of a special marker (M-20) consisting of a rectangular sign 24 inches by 9 inches in size, with a white arrow on a black background and the word DETOUR centered on the arrow. This sign should be made in rights and lefts so it can be mounted to point in either direction.

A supply of Detour or Temporary Markers should be kept on hand in all highway districts for prompt use as needed. When the regular route is reopened, all Detour or Temporary Markers should be removed immediately.

Section 112.—Cardinal Direction Marker (M-21)

The Cardinal Direction Marker shall be a plate 16½ inches by 8 inches in size, carrying the words EAST BOUND, WEST BOUND, NORTH BOUND, or SOUTH BOUND, in black letters on a white background. It may be mounted directly above a Route Marker (M-1, M-2) or an Oversize Route Marker to indicate the general direction of the route. It should be used only where motorists, in transferring from one route to another, might be confused as to the direction in which the intersected route would take them.

Section 113.—Destination Sign (D-1, D-2, D-3)

The Destination sign (D-1) shall be a horizontal rectangle carrying the name of a city, village, or other objective, a directional arrow, and the mileage to the place named. If several destinations are to be shown at a single point the several destination



M-20
24" x 9"

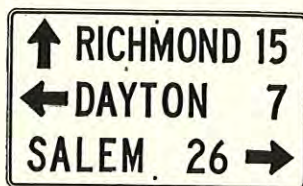


M-21
16½" x 8"

names may be placed on a single panel (D-2, D-3) with an arrow and the mileage for each name. If more than one destination lies in the same direction a single arrow may be used for such a group of destinations, but in this case adequate separation should be made between any group of destinations in one direction and other destinations in other directions. This may be accomplished by suitable design of the arrow, by spacing of the lines, or by a heavy line entirely across the panel.



D-1
Variable size



D-3
Variable size

Under some circumstances it is desirable and permissible to omit the mileage from the Destination sign. Within metropolitan areas, for example, distances mean little, and points of reference for the measurement of mileages are not easily defined. Frequently an indicated destination is so nearby as to warrant only the directional arrow. As a general rule, however, the mileages should be shown, particularly in rural areas. Care should be taken to avoid confusion where a mileage figure, by coincidence, is the same as the route number of a route leading in a different direction from the intersection.

The lettering, numerals, and symbols shall be either black upon a white background or, optionally on large signs, white upon a black background. On all important routes the signs should be re-letterized.

An arrow pointing to the right shall be at the extreme right of the sign, and an arrow pointing left or vertically shall be at the extreme left. The mileage figures shall follow after the destination name. Horizontal or sloping arrows should be of sufficient length to be clearly distinguishable from the vertical arrow. As a general rule the directional arrows should be horizontal or vertical, but where the intersection is irregular a sloping arrow will sometimes convey a clearer indication of the direction to be followed.

In rural districts on major routes, as defined in section 24, the sign shall have letters at least 6 inches in height for a single name (D-1) or for each of the names on a panel (D-2, D-3), and shall be long enough to accommodate the required name or names, each with its mileage and arrow symbol. On less important rural roads and in urban areas the signs shall have letters at least 4 inches in height for each name, with length in proportion. Where individual name signs are used all names in the same grouping shall have the same letter height and all signs in a group shall be of equal length, depending generally on the length of the longest destination name. Care should be exercised in erecting these assemblies to insure that all signs are in one plane so as to give a panel effect.

Destination signs are generally warranted:

1. At the intersections of U S or State numbered routes with other U S or State numbered routes.
2. At points where they serve to direct traffic from U S or State numbered routes to the business section of towns, or to other destinations reached by unnumbered routes.

Preferably not more than two or three names should be used in combination on one or more signs. As a general rule, the next important city or point of interest lying straight ahead should be at the top of the sign or assembly, and below it the next important destinations to the left and to the right, in that order. In the case of overlapping routes there should be shown only one destination in each direction on each route. If there is more than one destination in any direction the name of the nearest city or town should appear above that of any farther away.

Placing the vertical arrow at the top is not only consistent with the recommended arrangement for Route Marker assemblies, but also has the advantage that the arrow definitely points away from the other names shown. The sequence of left and right arrows also is like that specified for Route Marker assemblies, and gives priority position to the left turn, for which the driver must properly position himself in the center lane (secs. 99, 102, 104).

The choice of destination names must be somewhat flexible. The destination shown for each direction should ordinarily be the next county seat or the next principal city, rather than a more distant destination.

Section 114.—Location of Destination Signs

In rural districts, Destination signs or assemblies should generally be located not less than 100 feet nor more than 150 feet in advance of the intersection. This gives the motorist an opportunity to make up his mind as to the direction he wishes to turn before he reaches the intersection, and enables him to get into the proper lane for turning, if necessary.

The rural Destination signs shall be erected so that the bottom of the lowest sign will be not less than 2½ feet above the crown of the roadway, and the left-hand edge not less than 6 nor more than 10 feet from the roadway edge. Care should be taken that the sign or signs do not obstruct the driver's view of the intersection.

Supplementary or confirmatory Destination signs may be erected on the far right-hand corner of the intersection. They should be mounted at such a height as not to impair the view of the intersection for drivers of vehicles entering from any direction.

At important T or Y intersections it may be preferable to place Destination signs on the far side of the intersection, directly ahead of approaching traffic.

At rural intersections of other than major routes, the smaller Destination signs (not less than 4-inch lettering) may be used. **They shall be located and erected in the same manner as the larger signs.**

In residence and business districts Destination signs should be erected 50 to 100 feet in advance of intersections of numbered routes, and should ordinarily be of the smaller size. Supplementary Destination signs may be placed on the far right corner of the intersection facing approaching traffic. In general, only two signs should be in-

cluded in each installation, indicating the nearest town or city to right or left, respectively.

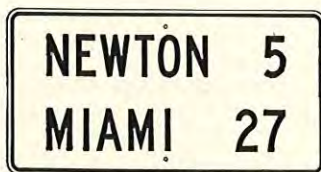
The signs shall be erected high enough to be seen over parked cars. They shall be not less than 7 feet to the bottom of the lowest sign in an assembly, and shall be set with a lateral clearance from the outside edge of the curb of not less than 1 foot. At intersections where it is impossible to erect individual posts the signs may, with permission from the proper authorities, be erected on trolley or light poles located in the proper positions. Where it is necessary that the signs project over the roadway they shall have a minimum clearance of $14\frac{1}{2}$ feet (fig. 2).

Destination signs pointing to the business district from a route that runs near but not through the business district may be erected at appropriate intersections. Signs placed to direct traffic from the business district to such a nearby route may also be used.

Figures 8, 9, and 10 show applications of Destination signs at intersections.

Section 115.—Distance Sign (D-4)

The Distance sign shall be a horizontal rectangle 40 inches by 20 inches in size, carrying the names of two incorporated cities, villages, or towns, and the mileages (to the nearest mile) to the centers of those places. Lettering shall be black on a white background, or optionally on enlarged signs, white on a black background.



D-4
40" x 20"

The top name shall be that of the next incorporated municipality along the route. The lower name shall be that of the city in which the greater portion of the through traffic is interested. In the case of long routes, the lower name may be varied on successive signs, alternating between several city, village, or town names. However, if the route is approaching a large city with no other cities near, the name of the large city should be repeated on successive signs. On interstate routes, as a second objective, the name of a city in the adjacent State may be shown.

Distance signs shall be erected on important routes leaving municipalities, and just beyond intersections of numbered routes in rural districts, or at approximately 10-mile intervals along the route. They should not ordinarily be used on any but major routes.

Distance signs shall be placed approximately 500 feet outside of the municipal limits on the right-hand side of the road, facing traffic leaving the municipality, or at the edge of the built-up district if it extends beyond the corporation limits. Where overlapping routes separate a short distance from the corporation limits, the Distance sign should be omitted at the corporation limits and should be erected 300 feet beyond the junction of the two routes.

Where, just outside of an incorporated municipality, two routes are concurrent and continue so concurrent to the next incorporated municipality, the top name on the sign placed at such a point should be that of the town where the routes separate; the lower name should be that of the city in which the greater portion of the through traffic is interested.

Distance signs shall be mounted with the bottom of the sign not less than 2½ feet above the crown of the roadway, and not less than 6 feet nor more than 10 feet from the edge of the roadway.

Figures 8, 9, and 10 show the use of Distance signs at rural intersections.

Section 116.—Street Name Sign (D-5)

Street Name signs should be erected and maintained by the municipality, and should be placed at all street intersections regardless of other route marking that may be present. A black and white color combination is recommended, but other contrasting colors may be used.



D-5
Variable size

The street name should appear in lettering at least 3 inches high, and, on more important streets, not less than 4 inches high. Supplementary lettering to indicate the type of street (e. g., street, avenue, road, etc.,) or section of city (e. g., N. W.) may be in smaller lettering, at least 2 inches high.

In business districts Street Name signs should be placed on diagonally opposite corners so that they will be on the far right-hand side of the intersection for traffic on the more important street. Signs indicating both streets should be erected at each location. They should be mounted as close to the corner as practicable, facing traffic on the cross street, with the nearest portion of each sign not less than 1 foot back from both curb lines. The signs should be mounted not less than 7 feet above the top of the curb, either at the same height or with one immediately above the other in a crossed position.

In residence districts Street Name signs should be mounted as in business districts, but a single location at each intersection will ordinarily suffice on all but the more important thoroughfares.

Care should be taken in all cases to insure that the signs are placed where they can easily be seen by motorists and pedestrians.

Section 117.—Information Signs (D-6)

Information signs are variable in size and in message. They include such information as names of rivers crossed, city, village, or town limits, county lines, State lines, elevations, etc.

Information signs shall be horizontal rectangles. They shall have black lettering on a white background or, optionally, white lettering on a black background. The size of lettering used should be such as to give adequate legibility for the purpose to be served. Typical signs of this type are illustrated in figure 11.

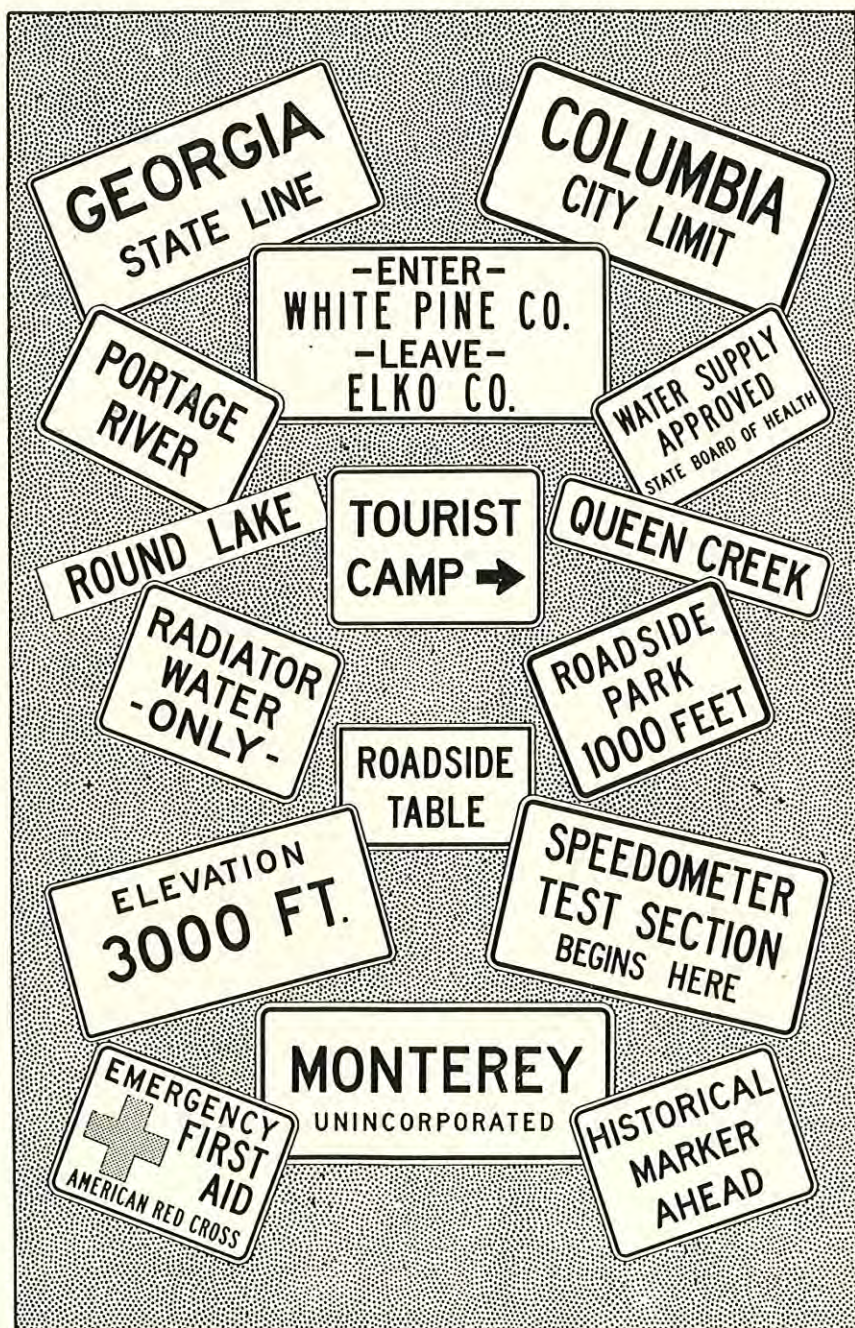


Figure 11.—Typical information signs, selected from State highway department manuals.

Since these signs are for information purposes and do not ordinarily serve to regulate, warn, or guide traffic (except perhaps indirectly in the case of city limits, etc.) the need for uniformity in design to insure automatic response is not altogether essential. They should, however, be of standard shape and color.

In rural districts, the Information sign should ordinarily be mounted from 6 to 10 feet from the pavement or roadway edge, and with the bottom not less than $2\frac{1}{2}$ feet above the crown of the roadway. In residence and business districts the lowermost edge should be not less than 7 feet above the curb, and no portion of the sign should be less than 1 foot back from the curb. A sign giving the name of a river may be mounted on the end of a bridge truss.

MARKINGS

A—INTRODUCTION

Section 118.—Functions and Limitations of Markings

Markings have definite functions to perform in a proper scheme of traffic control. In some cases they are used to supplement the regulations or warnings of other devices such as traffic signs or signals. In other instances they obtain results, solely on their own merits, that cannot be obtained by the use of any other device. In such cases they serve as a very effective means of conveying certain regulations and warnings that could not otherwise be made clearly understandable.

Markings also have definite limitations, especially when applied to pavement and curbs, where they may be entirely obliterated by snow, are not clearly visible when wet, and are not very durable when painted on surfaces exposed to traffic wear. In spite of these limitations, however, they have the advantage under favorable conditions that they can convey warning or information to the vehicle driver without diverting his attention from the roadway.

Section 119.—Legal Authority

Markings shall be placed only by the authority of a public body or official having jurisdiction for the purpose of regulating, warning, or guiding traffic.

Pavement and curb markings, being exclusively within the boundaries of public highways, should never be installed except by public authority. Delineators and markings on objects as a warning of their hazardous locations are also normally within the highway right-of-way, and should be subject to the same jurisdictional regulations.

A suitable model of legislation for the placing of markings is to be found in Act V of the Uniform Vehicle Code (secs. 19, 30, 31, 32, 33, 37). Interference with official markings is prohibited in section 38 of the same act.

Section 120.—Standardization

Markings, where used, shall be uniform in design, position, and application. As in the case of all other traffic control devices, it is imperative that markings be uniform so that they may be recognized and understood instantly.

Section 121.—Types of Markings

Markings as defined for the purposes of this manual are of a number of types:

1. Pavement markings:
 - (a) Center lines (secs. 128–130).
 - (b) Lane lines (secs. 131–133).
 - (c) No-passing-zone markings (secs. 134–136).
 - (d) Pavement edges (sec. 137).

- (e) Pavement-width transitions (sec. 138).
- (f) Approach to obstructions (sec. 139).
- (g) Streetcar clearance lines (sec. 140).
- (h) Turn markings (sec. 141).
- (i) Stop lines (sec. 143).
- (j) Cross-walk lines (sec. 144).
- (k) Route directions (sec. 145).
- (l) Approach to railroad crossing (sec. 146).
- (m) Parking space limits (sec. 147).
- (n) Word markings (sec. 148).
- 2. Curb markings for parking restrictions (sec. 149).
- 3. Object markings:
 - (a) Objects within the roadway (secs. 151-153).
 - (b) Objects adjacent to the roadway (sec. 154).
- 4. Reflector markers:
 - (a) Hazard markers (sec. 156).
 - (b) Delineators (sec. 157).

Section 122.—Materials

The most common method of applying pavement, curb, and object markings is by means of paint. A continuous improvement in paints and in equipment and methods of application has resulted in a very wide use of pavement markings. Equipment is in use that is capable of placing single, double, or triple striping on a highway, in different colors, and of solid or broken type of line, while operating at a speed of 10 to 15 miles per hour. Hand equipment can be used to place transverse or special markings, at intersections or elsewhere, at a reasonable cost.

A relatively recent development in pavement markings is the use of minute glass "beads" (actually true spheres) embedded in the pavement-marking material to produce a retrodirective reflecting surface. The glass-beaded surface returns a greatly increased proportion of the incident light back in the direction of its source, and causes the markings to appear luminous at night under normal head-lighting. While the beads have little or no effect in the daytime, the visibility of the markings by night is greatly improved. Although the initial cost of such reflectorized markings is considerably higher than for ordinary traffic paint, a number of highway departments have reported that the increased life of the markings, especially at heavily traveled locations, more than compensates for the difference in cost.

Pavement markings may also be in the form of small units of metal or other material attached to or set into the pavement surface. Such units may be rectangular, round, or of special shape, and may be assembled into solid or broken lines.

Flat units on or in the pavement surface shall be of permanent colors as specified for pavement markings, and shall be set so that their upper surfaces are essentially flush with the pavement surface. They may be placed in continuous contact, or separated by small spaces approximately equal to the length of a single unit. Either type of line may be used where a solid line is prescribed in this manual. Particular care should be taken to see that alinement and spacing are accurate, to insure a good appearance.

Metal inserts shall have a surface that will remain bright under the action of traffic, thus contrasting with the color of the pavement. Nonmetallic inserts shall be of permanent colors as specified for pavement markings. Inserts shall be not less than 4 inches in diameter if round, or of approximately equivalent area

if of other shape, and shall be spaced not more than 16 inches apart, center to center, on transverse lines, nor more than 36 inches apart on longitudinal lines. They shall have rounded surfaces, presenting a smooth contour to the wheels of vehicles, and shall not project more than one-half inch above the level of the pavement. They shall be permanently fixed in place by anchor bolts or similar effective devices.

Similarly, unit letters, symbols, or stripes may be attached to or set into the pavement surface, as an alternative type of pavement marking. These should be essentially flush with the pavement surface, and should not become unduly slippery when wet, especially if they are of considerable area. They should be of permanent colors as specified for pavement markings.

Metal and plastic inserts and flat marker units in or on the pavement surface are used principally in urban areas, where heavy traffic rapidly destroys painted markings, and where frequent repainting not only is costly but causes undue traffic delays. In rural areas speed of application makes painting the preferred form of marking.

While successful experiments have been reported with permanent built-in pavement markings of white or colored concrete or inlaid bricks or blocks, their use has not been widespread.

The use on the pavement surface of small metal or plastic studs with inserted reflector buttons is not recommended. Experience has shown that they are destroyed by snow plows, they cannot be kept clean and effective, and they are a hazard to motorcycles.

Large "mushroom" buttons, or bars, of cast iron or concrete several inches high, with or without reflectors, lights, symbols, or messages, are favored in some cities to mark pedestrian islands or to assist in channelizing traffic. In these applications they are, in effect, curbs or islands (secs. 322, 325, 341, 349, 360). They are not a suitable alternative to signs or pavement markings. They should not be located where they constitute an unexpected hazard for motor vehicles, and their use on rural highways is strongly disapproved.

Object markings are ordinarily painted directly on the surface of the obstruction. If the surface will not retain paint readily, some flat surface of wood or metal should be painted with the proper marking and attached to the obstruction. Where a reflectorized coating is desirable, it will often be necessary to use a separate surface for satisfactory application. Reflecting buttons or clusters may be attached directly to the obstruction or installed on separate posts immediately in front of it.

Delineators and hazard markers may consist of single reflectors, clusters of reflectors, or small panels of uniform shape covered with a reflecting coating, mounted on separate posts. To be effective they must be of retrodirective character and of adequate brilliance.

Section 123.—Colors

Pavement markings shall be either white or yellow in color.

The correct color for yellow traffic paint is the same as that specified for highway signs. Color cards showing this "highway yellow" may be obtained from the Public Roads Administration.

Bright metal buttons are to be regarded as the equivalent of white paint in pavement markings.

White shall be used for:

- | | |
|---|--------------------------|
| 1. Center lines on two-lane rural roads and city streets. | 6. Stop lines. |
| 2. Lane lines. | 7. Cross-walk lines. |
| 3. Pavement edges. | 8. Parking space limits. |
| 4. Streetcar clearance lines. | 9. Route directions. |
| 5. Turn markers. | 10. Word markings. |

For the following markings it is recommended that yellow be used, but white is permissible:

1. Double center lines on multi-laned pavements.
2. No-passing barrier lines at:
 - (a) No-passing zones on two- and three-lane roads.
 - (b) Pavement-width transitions.
 - (c) Approaches to obstructions in the center of the roadway.
 - (d) Approaches to railroad crossings.

The markings for which yellow is recommended are all solid guide lines or regulatory lines to the left of which it is unsafe or illegal to travel when they are applied as prescribed in this manual. Yellow is favored for several reasons:

1. It contrasts with the normal white center or lane lines and thus gives emphasis to the hazard.
2. Yellow has been accepted as a symbolic warning color in signs and signals.
3. It is consistent with the standard for no-passing-zone markings hitherto approved by the American Association of State Highway Officials and in use in many States.

Curb markings to show parking prohibitions covered by signs or ordinance shall be yellow.

Markings on vertical surfaces of objects within the roadway or dangerously close thereto shall consist of alternate black and white stripes.

Objects adjacent to the roadway, such as guard rails, trees, and rocks, may be painted white as a useful guide to night traffic.

In reflector markers, delineators shall be white, and markers indicating the location of hazardous objects shall be white or yellow.

Section 124.—Types of Striping

A broken line shall be used for center or lane lines where these lines are only guide lines that may be crossed at the discretion of the driver.

Since most center and lane lines are only for guidance, the saving in paint through the use of broken lines is an important economy. High-speed striping machines have been constructed that are capable of repainting broken lines accurately and neatly, permitting a saving of more than 60 percent in paint, with little or no increase in the cost of application.

A broken line, with segments and gaps well proportioned, appears to be as effective as a solid line for guide purposes. On rural highways a commonly used standard is 15-foot segments with 25-foot gaps. In the application of a given gallonage of paint per mile, such relatively short segments will give a better line than if longer segments, with correspondingly longer gaps, are used. On the other hand, very short segments and gaps have been found to cause an unpleasant flickering sensation.

On urban streets the line segments and gaps, especially the latter,

should be considerably reduced in length. Short sections of broken line, such as are used for intersection approaches, require the use of short segments, closely spaced.

Broken lines are also prescribed for streetcar clearance lines, and for turn markings (secs. 140, 141).

A solid line shall always be used for longitudinal markings where the line is of a regulatory character and is not to be crossed, that is, for center lines of two-way multi-laned roads with an even number of lanes, and for lines indicating no-passing zones.

In a combination striping of solid and broken lines, the solid or barrier line has significance only if it is on the right-hand side of the combination stripe, as viewed by the driver, i. e., in or adjacent to the traffic lane to which it applies.

Section 125.—Width of Lines

Longitudinal pavement lines shall be from 4 to 6 inches wide.

The most common width is 4 inches, but 6-inch lines, favored by a number of highway departments, provide added visibility. Narrower 3-inch lines have been used as a means of economizing in paint, but they are not regarded as adequate for standard use.

Transverse lines on pavements must be much wider than longitudinal lines to be equally visible. Stop lines may have to be as wide as 24 inches where approach speeds are high.

Section 126.—Reflectorization

Reflectorization for better night visibility is desirable for almost all markings, but it is neither a practicable nor necessary requirement in all cases. Reflectorization is of doubtful value on well-lighted city streets, for example, and it is not ordinarily essential for center or lane lines where there are no special hazards. At least the following markings should normally be reflectorized:

1. Center lines on multi-laned pavements.
2. No-passing barrier lines at:
 - (a) No-passing zones on two- and three-lane roads.
 - (b) Pavement-width transitions.
 - (c) Approaches to obstructions in the roadway.
 - (d) Approaches to railroad crossings.
3. Striping on vertical surfaces of objects in and adjacent to the roadway.

Section 127.—Maintenance

All necessary markings shall be kept in good order and clearly visible at all times. Unless this is done they may create serious hazards by giving a false sense of security, especially in the case of cross walks.

The frequency of repainting depends on the type of surface, composition and rate of application of paint, climate, and volume of traffic. Particular care should be taken, especially in the case of broken lines, to paint over the old markings as exactly as possible, otherwise they will appear increasingly ragged after successive repaintings.

B—PAVEMENT AND CURB MARKINGS

Section 128.—Center Lines

A center line is used to designate the center of the traveled portion of a roadway carrying traffic in both directions. Under some circum-

stances, as at a pavement-width transition, it need not be at the geometrical center of the pavement. On all major rural highways having an even number of lanes, and on many urban streets and less important rural roads, center lines are necessary and should be applied throughout the entire length of the pavement. In urban locations and on some rural roads where a continuous center line is not required, short sections of center line are useful on approaches to busy intersections, marked cross walks, or railroad crossings, and around curves or over hillcrests. When so used, the center line serves both to warn of any unusual condition and to organize and control traffic through a hazardous or congested zone.

A line marking the center of a one-way roadway is a lane line, as described in section 131.

Section 129.—Center Lines on Rural Roads

The center line on a two-lane paved rural highway shall be a broken white line, not less than 4 nor more than 6 inches wide. Line segments 15 feet in length, with 25-foot gaps, are recommended.

Where a center line is applied only at special locations on a highway, it should generally be used where overtaking and passing is unsafe, as over hillcrests, around curves, and at railway grade crossings and intersections, or wherever traffic control requires a clear indication of the roadway center. At intersections the line should extend in advance of the intersection a sufficient distance to keep vehicles definitely in single line while approaching. **Short sections of center lines used for regulatory purposes, requiring that drivers keep to their proper lane, shall be solid white lines.**

On four-lane undivided rural pavements, or on pavements of a greater even number of lanes, the center line shall consist of two solid lines, each not less than 4 inches nor more than 6 inches wide, separated by a space of not less than 2 inches. Such lines should normally be reflectorized.

Since this center line is, in effect, a continuous no-passing striping, to the left of which it is illegal to drive (sec. 134), it is recommended that the two lines be yellow. As an alternative, white lines are permissible.

As a guide to the application of center-line markings the following warrants are suggested:

1. Center lines should be placed throughout the length of:
 - (a) Two-lane pavements carrying average annual traffic volumes in excess of 2,000 vehicles per day.
 - (b) Two-lane pavements narrower than 20 feet carrying average annual volumes in excess of 1,000 vehicles per day.
 - (c) Two-lane pavements narrower than 18 feet carrying average annual volumes in excess of 500 vehicles per day.
 - (d) All four-, six-, and eight-lane undivided pavements.
2. Center lines should also be placed on all two-lane pavements carrying annual traffic volumes in excess of 300 vehicles per day at the following locations:
 - (a) On the approaches to the crest of a hill where the clear view ahead is less than 500 feet.
 - (b) On the 100 feet in advance of and beyond any curve having a radius of less than 600 feet or where the sight distance is less than 500 feet.
 - (c) On the approach to a traffic control signal or arterial highway for a distance of not less than 100 feet from the Stop line, and as much more as may be necessary to cover the distance within which vehicles are commonly aligned.
3. Center lines should also be placed at locations where the accident record indicates the need for them, and on hard-surfaced roads in areas where the entire roadway is likely to be obscured frequently, as by fog.

Section 130.—Center Lines on Urban Streets

Center lines on city streets shall be broken white lines, not less than 4 inches nor more than 6 inches wide. To preserve the effect of continuity where traffic is heavy, speeds are low, or blocks short, the line segments, and especially the gaps, should be relatively short.

Long sections of such lines should not be used on streets providing less than two lanes for free-moving traffic in each direction, exclusive of parking lanes. This minimum street width does not apply to the use of short sections of center lines around curves, over hillcrests, or on approaches to important intersections and marked cross walks. **Short sections of center line for regulatory purposes shall be of solid design.**

Small units of metal or other material attached to or set into the pavement surface are frequently used in cities as an alternative to painted markings. These are discussed in section 122.

On wide, high-speed boulevards, and on controlled-access highways in urban areas, center-line standards shall be the same as those for rural highways.

Applications of center lines are shown in various illustrations herein, particularly figures 5, 10, 12, 14, and 17.

Section 131.—Lane Lines

Lane lines are helpful in the organization of traffic in its proper channels, and in increasing the efficiency of the use of the roadway surface at congested locations. They should be used:

1. On all rural highways with an odd number of traffic lanes.
2. In addition to the regular center line, on all rural highways of four, six, or eight lanes.
3. At important intersections, at cross walks, and in dangerous locations, on both rural highways and city streets.
4. At congested locations, particularly on city streets, where the roadway will accommodate more lanes of traffic than would be the case without the use of lane lines. These include:
 - (a) Locations between loading islands and sidewalk curbs.
 - (b) Other locations where the normal lane width is decreased.
 - (c) Approaches to widened intersections.
5. On important one-way streets or highways where maximum efficiency in utilization of the roadway is desired.

Applications of lane lines are illustrated in figures 14, 15, and 17.

Section 132.—Lane Lines on Rural Roads

Lane lines on rural roads shall be broken white lines, not less than 4 inches nor more than 6 inches wide. Line segments 15 feet long, with 25-foot gaps, are recommended. The transverse spacing of lane lines, that is, the lane width, should not normally be less than 10 feet.

Section 133.—Lane Lines on Urban Streets

Lane lines on city streets shall be broken white lines, not less than 4 inches nor more than 6 inches wide. Due to relatively lower speeds, the line segments, and especially the gaps, should normally be shorter than in rural areas. In limited sections of lane lines, as at intersection approaches or between loading islands and sidewalk curbs, the line segments and gaps may be as short as 4 feet and of equal length.

The lane width defined by lane lines should not normally be less than 10 feet, but a minimum of 9 feet is permissible where a maximum

number of lanes must be made available, as at a signalized intersection where provision must be made for the most efficient storage of stopped vehicles in a street width reduced by the presence of a loading island.

On wide, high-speed boulevards and on controlled-access highways in urban areas the standards for lane markings shall be the same as those for rural highways.

Section 134.—No-Passing Zones

No-passing zones should be established at vertical or horizontal curves and elsewhere on two- and three-lane highways where passing must be prohibited because of dangerously restricted sight distances or other hazardous conditions.

A no-passing zone shall be marked by a solid barrier line placed as the right-hand element of a combination stripe along the center or lane line. It is recommended that this barrier line be yellow (sec. 123), although white is a permissible alternative.

The combination line may consist of either of the following, as illustrated in figure 12:

1. A normal broken white center or lane line continuing through the no-passing zone, with the solid barrier line placed to the right of it. Where no-passing zones in opposite directions overlap on a two-lane roadway there will be a solid barrier line on each side of the broken center line. Where the no-passing restriction applies only in the opposing direction, the barrier line will appear to the left of the broken center or lane line and will not have any controlling effect except on traffic in the opposing direction.

2. A double line replacing the single broken center line on a two-lane roadway, of which the right-hand stripe is the solid barrier line. Where no-passing zones in opposite directions overlap, there will be a double solid line, and where the no-passing restriction applies only in the opposing direction the solid line will be to the left of a broken line and will not have any controlling effect.

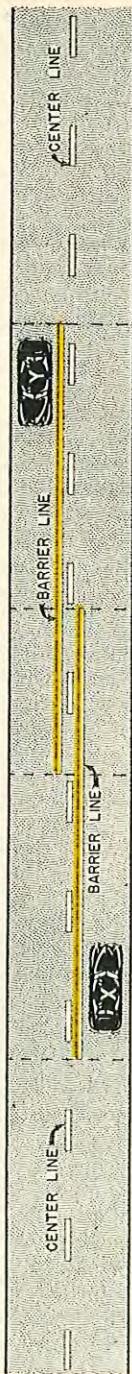
The barrier line shall be not less than 4 nor more than 6 inches wide, and shall be separated from the adjacent stripe by a space of not less than 2 nor more than 4 inches. It should normally be reflectorized for increased emphasis.

On unimportant two-lane roadways carrying little traffic, a center-line marking may be desirable although the marking of no-passing zones by means of barrier lines may not be economically warranted. Under such conditions a single-line marking, consisting of a broken white center line where passing is permitted and a solid white center line throughout no-passing zones in either direction, is recognized as a permissible alternative to the barrier-line design prescribed above. A single center line can be placed more cheaply, and on a narrow roadway is subject to less traffic wear than the double or triple barrier-line design. The single-line design, however, should be used with great caution. It lacks the directional characteristic of the barrier-line design for no-passing zones. Thus it forces the driver to stay on his side of the roadway for some distance after his sight distance has become adequate for passing, or it throws on him the responsibility for deciding when it is safe to pass, thus destroying the barrier significance of the solid line. Particular care should be taken to avoid an unnecessary and possibly confusing mixture of the two types of design in any given area.

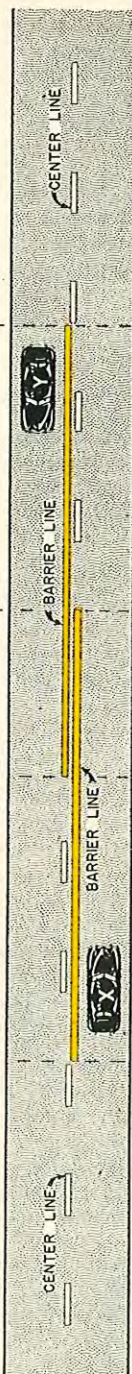
Section 135.—No-Passing Zones on Two- and Three-lane Roadways

On a two-lane roadway the combination no-passing line shall follow the center line throughout the no-passing zone. On a three-

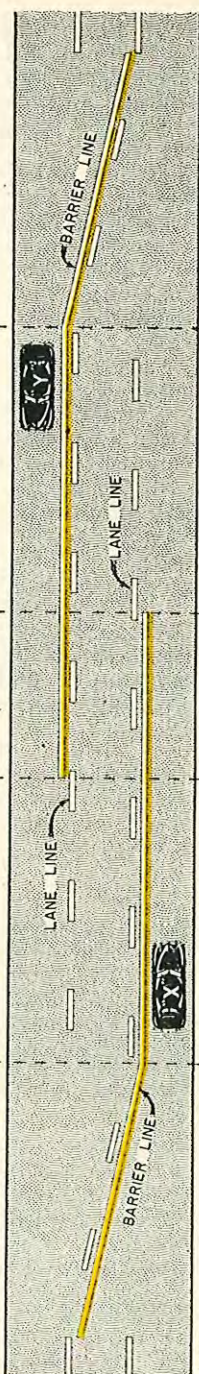
A-TWO-LANE ROAD-TRIPLE STRIPE DESIGN



B-TWO-LANE ROAD-DOUBLE STRIPE DESIGN



C-THREE-LANE ROAD



NOTE:

ON THREE-LANE ROAD, EXTEND COMBINATION STRIPE ACROSS CENTER LANE IN ADVANCE OF NO-PASSING ZONE AT ANGLE OF NOT LESS THAN 20 TO 1.

NOTE:

CENTER LINES AND LANE LINES ARE BROKEN WHITE LINES. BARRIER LINES ARE SOLID YELLOW OR WHITE LINES (PREFERABLY YELLOW).

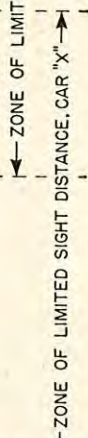


Figure 12.—Standard pavement markings for no-passing zones.

lane road the combination line shall start from the left-hand lane line of the center lane and shall extend at an angle of not less than 20 to 1 across the center lane to the right-hand lane line at the beginning of the no-passing zone, and thence extend along the lane line to the end of the zone (fig. 12).

No-passing-zone signs (R-11, R-12; secs. 39, 40) may be used to supplement the pavement markings here prescribed.

It is assumed that on highways of four or a greater even number of lanes it is not necessary to cross the center line to overtake and pass other vehicles. No specifications, therefore, are provided for the marking of no-passing zones on such highways. The double center line is to be regarded as a continuous no-passing marking, consisting of two barrier lines which must not be crossed from either side.

Section 136.—Warrants for No-Passing Zones

The warrant for the establishment of a no-passing zone depends on the assumed design speed of the road and the minimum sight distance necessary for safe passing at that speed. Sight distance on a vertical curve is the distance at which an object 4½ feet above the pavement surface can just be seen from another point 4½ feet above the pavement, as illustrated in figure 13. Sight distance on a horizontal curve is determined in similar fashion, measuring around the embankment or other obstruction that cuts off the view on the inside of the curve. **A curve shall warrant a no-passing zone, and shall be so marked, when the minimum sight distance for the assumed design speed is equal to or less than that listed below:**³

Design speed (miles per hour):	Minimum sight distance (feet)
30.....	500
40.....	600
50.....	800
60.....	1,000
70.....	1,200

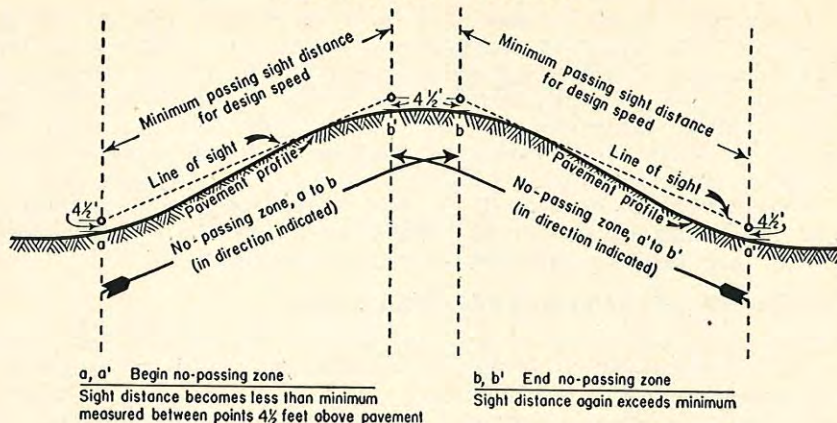
The beginning of a no-passing zone, point *a* in figure 13, is that point at which the sight distance first becomes less than that specified in the above table. The end of the marking, point *b*, is that point at which the sight distance again becomes greater than the minimum specified. **In no case shall the marking be less than 500 feet in length. If the actual no-passing distance is less than 500 feet in length, the additional length of marking shall be added at the beginning of the zone.**

For methods of determining the beginning and end of no-passing zones, see *A Policy on Criteria for Marking and Signing No-Passing Zones on Two and Three Lane Roads*, American Association of State Highway Officials; or the *Traffic Engineering Handbook*, published jointly by the Institute of Traffic Engineers and the National Conservation Bureau.

On urban streets it is not ordinarily necessary to mark no-passing zones. Speeds are generally low, and a normal center line is usually sufficient to keep vehicles in line. On boulevards or parkways, where no-passing zones may have to be marked, the standards should be the same as for rural highways.

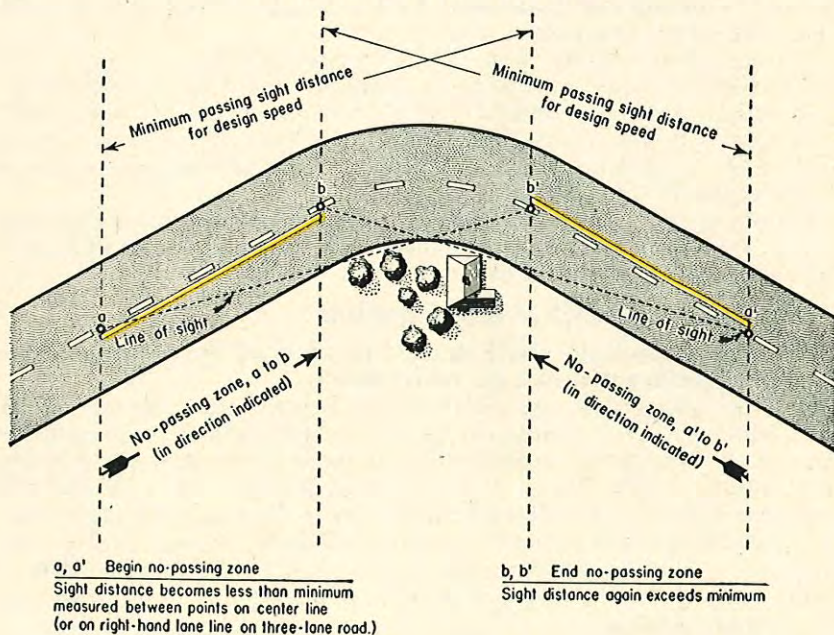
³ Adapted from *A Policy on Criteria for Marking and Signing No-Passing Zones on Two and Three Lane Roads*, American Association of State Highway Officials.

VERTICAL CURVE



Note: No-passing zones in opposite directions may or may not overlap, depending on alignment.

HORIZONTAL CURVE



Note: No passing zones in opposite directions may or may not overlap, depending on alignment.

Figure 13.—Method of locating and determining the length of no-passing zones on vertical and horizontal curves.

Section 137.—Pavement Edges

Line markings on the pavement have sometimes been used along the sides of the roadway, especially on bridges, to indicate the limit of safe approach to the edge of the pavement. Experience has shown that such lines are easily mistaken for center or lane lines, with the result that drivers attempt to pass to the right of them and so run off the road. They are therefore not recommended. Reflector markers are much preferable for the purpose intended (secs. 156, 157).

Pavement edge lines shall be solid white lines, not less than 4 nor more than 6 inches wide. When used, they shall supplement rather than replace standard center and lane lines.

Section 138.—Pavement-Width Transitions

Line markings should be used to indicate points where the pavement width changes to a lesser number of lanes. There are a number of situations possible, as illustrated in figure 14, depending on which lanes must be offset or cut out, and the amount of offset. One or more lane lines must be discontinued and the remaining center and lane lines must be connected in such a way as to merge traffic into the reduced number of lanes.

Lines marking pavement-width transitions shall be not less than 4 nor more than 6 inches wide, and of standard center- or lane-line design. Converging lines shall have a length of not less than 20 times the offset distance.

Through the transition area, in the direction of convergence, the line separating the opposing directions of traffic should be of no-passing-zone design, either the double solid center line of a multi-laned road or a normal broken center line with an adjacent barrier line as prescribed for no-passing zones (sec. 134). Such no-passing markings should normally be reflectorized.

Pavement-width transition lines, in themselves, are not a sufficient warning at such locations, and should be used only to supplement standard signs, guardrails, or delineators.

Section 139.—Approach to an Obstruction

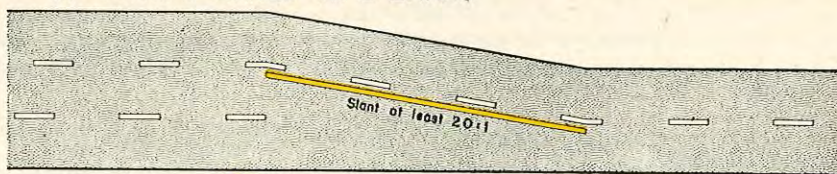
Pavement markings shall be used to warn of the approach to a fixed obstruction within a paved roadway.

Obstructions within the roadway are hazards that should not be permitted to exist if avoidable, but where they cannot reasonably be eliminated everything possible should be done to prevent vehicles from colliding with them. An obstruction may be in the center of the roadway, in which case all traffic must keep to the right of it, or it may be so located as to be between two lanes of traffic moving in the same direction. The markings in either case must be designed to deflect traffic away from the obstruction by a diagonal line or lines of unmistakable meaning.

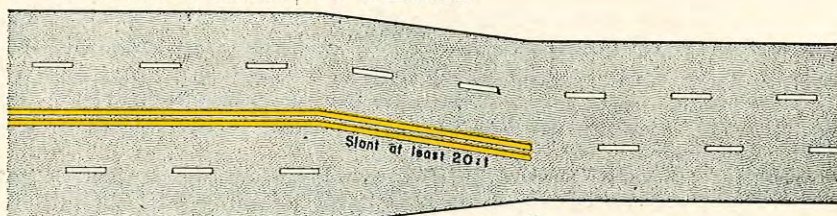
Obstruction pavement markings shall consist of a diagonal line, or lines, extending from the center or lane line to a point 1 foot to the right side, or to both sides, of the approach end of the obstruction (fig. 15).

The length of the diagonal markings should be determined by the formula $L = S \times W$ where L equals the length in feet, S the design speed in miles per hour, and W the width of the obstruction in feet.

A. - FROM 3 LANES TO 2 LANES



B. - FROM 4 LANES TO 3 LANES



C. - FROM 4 LANES TO 2 LANES

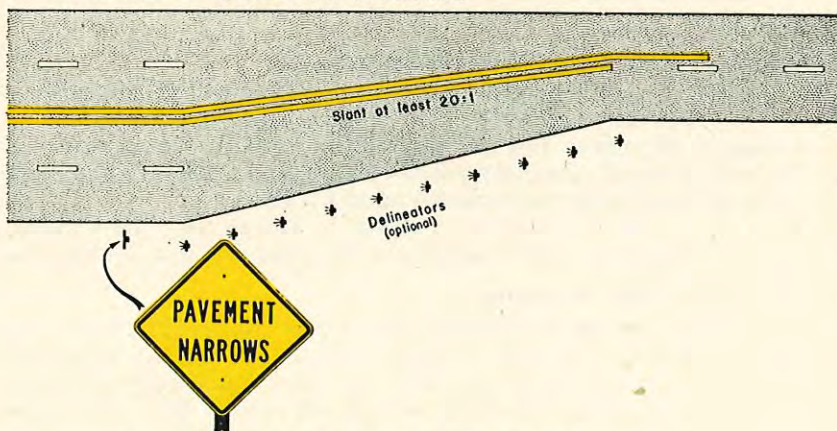


Figure 14.—Typical pavement-width transition markings.

In no case shall the diagonal line be less than 150 feet in length in rural areas or 50 feet in urban areas.

If traffic is required to pass only to the right, the diagonal line shall be marked to the right and shall be of one of the following designs:

1. A normal broken center line flanked by a solid barrier line, as specified for no-passing zones (sec. 134). The barrier line shall extend along the center line in advance of the diagonal line for a further distance equal to the length of the diagonal line.

2. On a roadway not marked with a continuous center line, a solid line which shall be extended, on the roadway center line, a further distance in advance equal to the length of the diagonal line.

3. On roads of four lanes or more a simple continuation of the double center line prescribed for such roads (sec. 129).

In addition, a solid white diagonal line may be extended to the left of the obstruction, to outline the triangular area from which traffic must be excluded for safety.

If traffic may pass either to right or left of the obstruction, there shall be two solid white lines diverging from the lane line, one to either side of the obstruction. In advance of the point of divergence a single solid line shall be extended in place of the normal broken lane line for a distance equal to the length of the diverging lines.

All lines used in obstruction approach markings shall be not less than 4 nor more than 6 inches wide. They should preferably be reflectorized.

As an added safeguard it is desirable, especially where traffic is permitted to pass to both right and left of an obstruction, to place broad transverse, diagonal, or longitudinal lines in the triangular area between the guide lines, as shown in figures 15 and 20.

Similar markings are desirable at channelizing islands not so designed as to divert traffic naturally from them.

Obstruction approach markings shall be used only to supplement adequate markings on the obstruction itself as prescribed in section 151.

Section 140.—Streetcar Clearance Lines

It is often desirable to mark lines on the pavement to indicate the limits and the clearance of the overhang on turning streetcars.

Streetcar clearance lines shall be broken white lines, with segments and gaps of equal length not exceeding 2 feet. They shall be not less than 4 nor more than 6 inches wide.

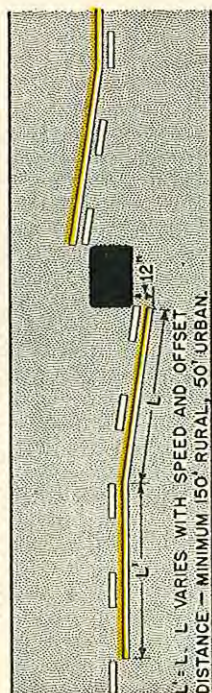
On curves of short radius it is necessary to use very short dashes and spaces, to preserve the appearance of continuity in a broken line.

Section 141.—Turn Markings

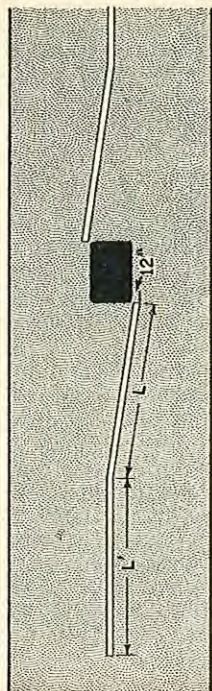
Markings to restrain drivers from starting left turns before reaching the intersection, or to guide turning vehicles, are sometimes used at intersections. Such markings have not been satisfactorily standardized, but if used they should be so designed as to indicate the proper course for turning vehicles without being needlessly confusing to through traffic or traffic making other turns. Typical designs are shown in figures 16 and 42.

Lines used in turn markings shall be broken white lines, not less than 4 nor more than 6 inches wide. As in the case of street-

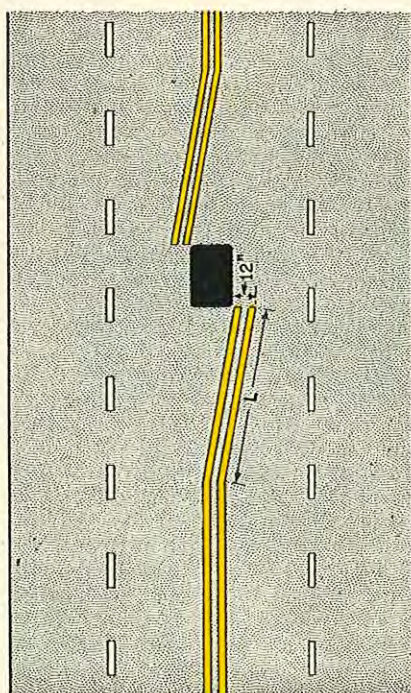
A.-CENTER OF TWO-LANE ROAD
WITH CONTINUOUS CENTER LINE



B.-CENTER OF TWO-LANE ROAD
WITHOUT CONTINUOUS CENTER LINE



C.-CENTER OF FOUR-LANE ROAD



D.-TRAFFIC PASSING BOTH SIDES OF OBSTRUCTION

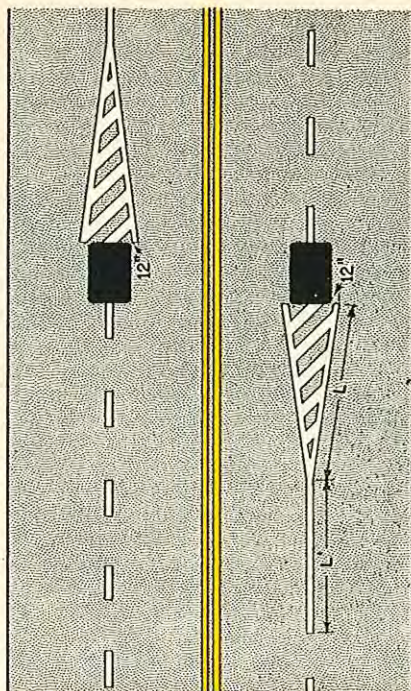


Figure 15.—Approach markings for obstructions in the roadway.

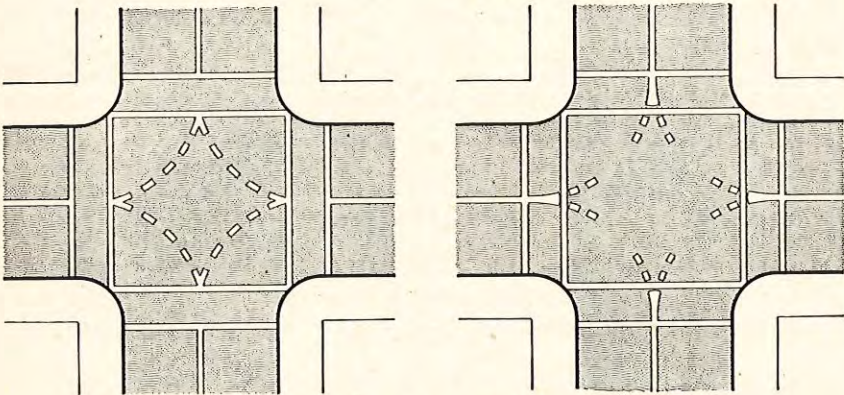
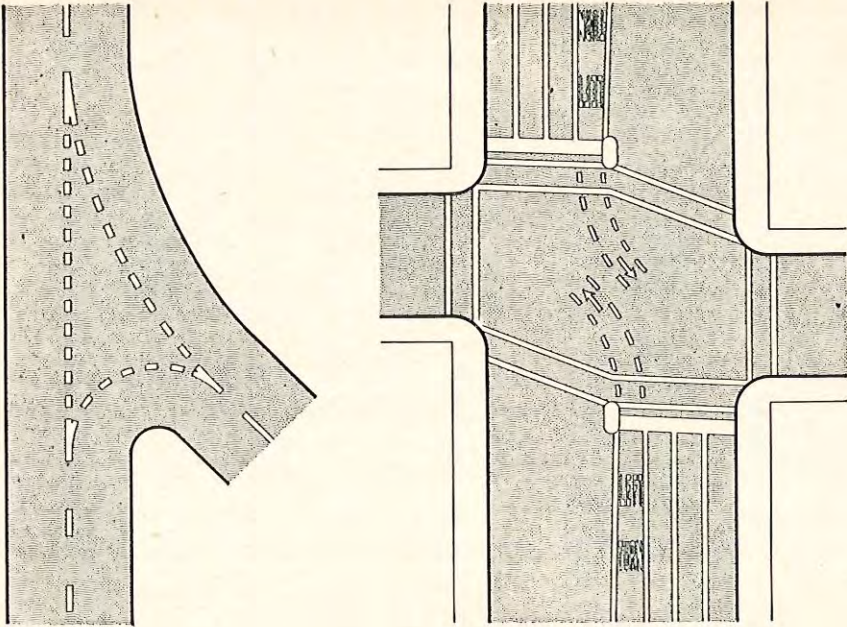


Figure 16.—Typical designs for turn markings on pavements.

car clearance lines, they should be made up of short dashes and short spaces.

Section 142.—Transverse Lines

Because of the low angle at which pavement markings are viewed from an approaching vehicle it is necessary that all transverse lines be proportionately widened to give visibility equal to that of longitudinal lines, or to avoid apparent distortion where longitudinal and transverse lines are combined in symbols or lettering. This applies particularly to Stop lines, cross-walk markings, railroad-crossing markings, and word markings.

Particular attention must be given to the maintenance of transverse lines which, because of their position on the pavement, are subject to constant wear by every vehicle that passes.

Section 143.—Stop Lines

Stop lines (or Limit lines) should be used in both rural and urban areas only where it is important to indicate the point behind which vehicles are required to stop in compliance with a Stop sign, traffic signal, officer's direction, or other legal requirement.

Stop lines shall be solid white lines, not less than 12 nor more than 24 inches wide. They shall extend across all approach lanes, usually to the center line (figs. 3, 17).

On urban streets where speeds are not high a width of 12 to 18 inches is usually sufficient.

Stop lines, where used, should ordinarily be placed 4 feet in advance of the nearest cross-walk line. In the absence of a marked cross walk, the Stop line should be placed at the desired stopping point, in no case more than 30 feet or less than 4 feet from the nearest edge of the intersecting roadway.

If a Stop line is used in conjunction with a Stop sign, it should ordinarily be placed in line with the Stop sign. However, if the sign cannot be located exactly where vehicles are expected to stop, the Stop line should be placed at the stopping point.

The word STOP shall not be placed on the pavement in advance of a Stop line, unless every vehicle is required to stop at all times.

Section 144.—Cross-walk Lines

Cross walks should be marked at all intersections where there is material conflict between vehicular and pedestrian movement. Marked cross walks should also be provided at other appropriate points where there is substantial pedestrian movement, as at long loading islands (sec. 320), or where pedestrians are permitted to cross between intersections, or where pedestrians could not otherwise recognize the proper place to cross.

Cross-walk lines, in both rural and urban areas, shall be solid white lines, marking both edges of the cross walk. They shall be not less than 4 nor more than 12 inches wide (fig. 17). If no advance Stop line is provided, it may be desirable to increase the width of the Cross-walk line on the approach side to as much as 24 inches.

On urban streets, where speeds are relatively low, a width of 6 inches is usually adequate.

The width of the cross walk between Cross-walk lines is usually determined by the width of the sidewalks so connected. **The width shall in no case be less than 6 feet.**

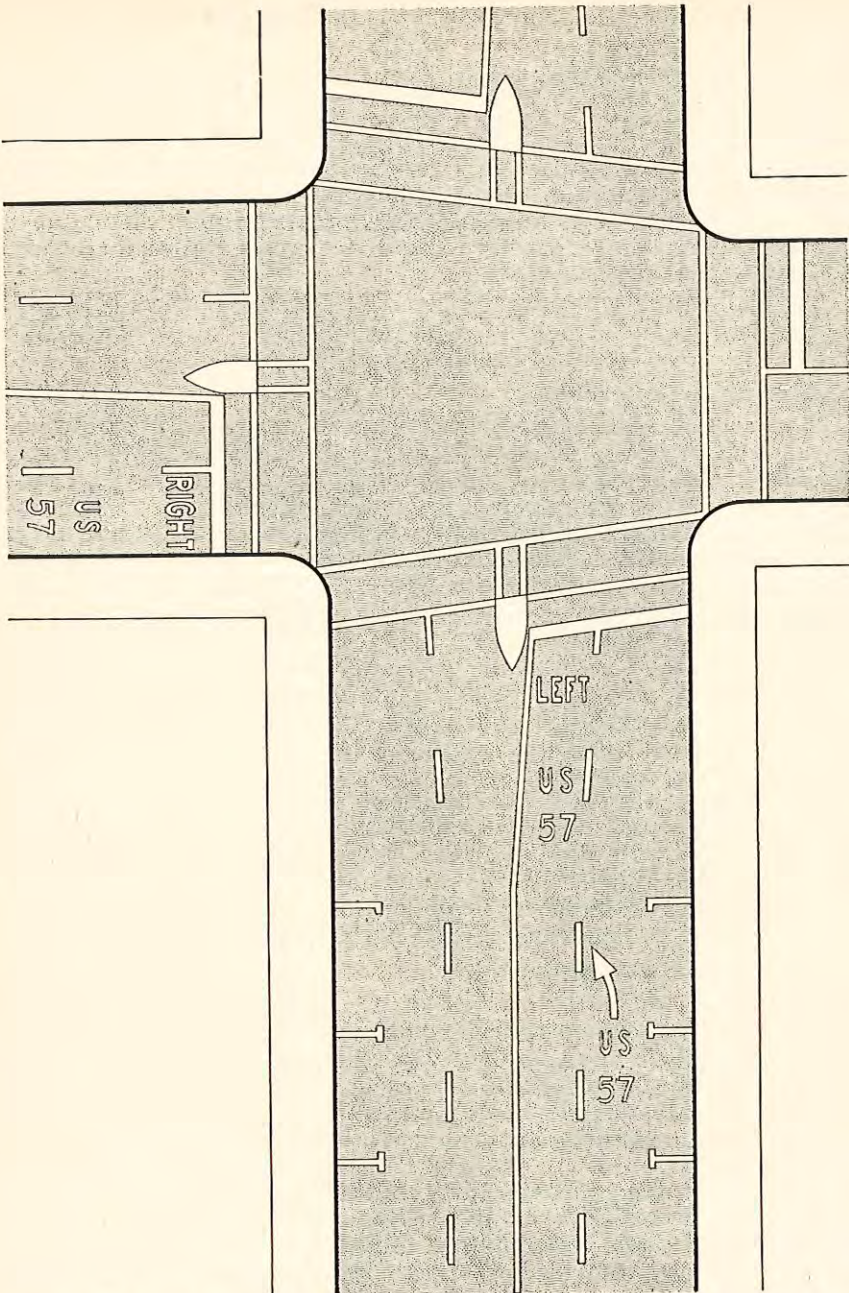


Figure 17.—Typical urban pavement markings, showing center lines, lane lines, Stop lines, cross-walk lines, parking-space limits, and route markings.

To facilitate pedestrian cooperation in traffic regulation, pedestrians should know exactly where they are to cross the street, and should feel reasonable security not only against vehicles approaching the intersection, but also against those turning within it. Single-line cross-walk markings fail in this, and are strongly disapproved. Two lines are necessary to define the cross-walk area, and should always be used.

Section 145.—Route Directions

As a supplement to standard route markers, or where directions cannot be satisfactorily indicated by any other means, special directional markings can sometimes be used on the pavement. These may consist of one or more arrows, with or without route numbers, in the center of the lane. A typical example is illustrated in figure 17.

Directional markings shall be white in color.

Section 146.—Approach to Railroad Crossing

Pavement markings consisting of a cross, the letters RR, a no-passing center line, and certain transverse lines shall be placed on all paved approaches to railroad crossings, except at minor sidings or spurs or in urban areas where other protection is afforded. Such markings shall be white except for the no-passing barrier line, which should preferably be yellow. These markings should normally be reflectorized.

The design of railroad-crossing pavement markings shall be essentially as illustrated in figure 18. The symbol and letters are elongated to allow for the low angle at which they are viewed.

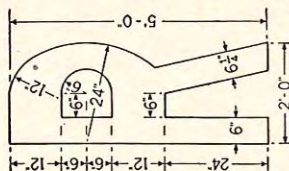
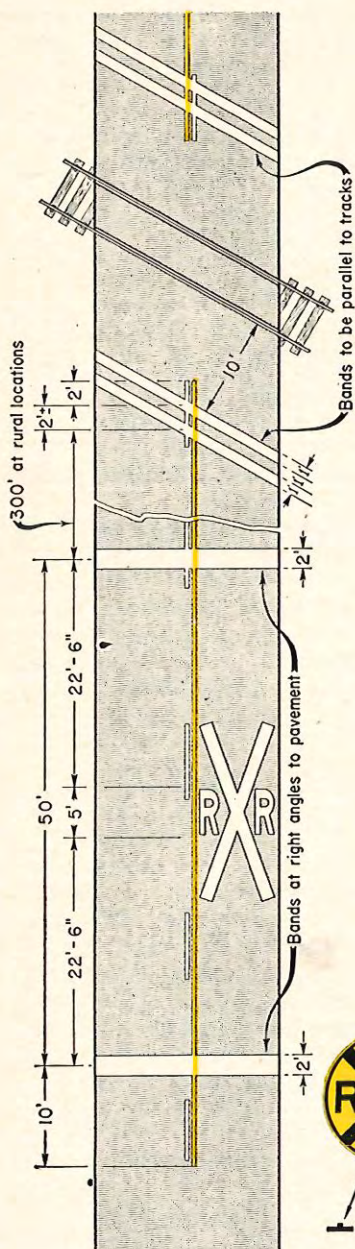
While these markings have value as a means of attracting the attention of the driver to the proximity of a railroad grade crossing, because they are distinctively different from all other pavement markings, they are only auxiliary to the standard signs or signals (secs. 88, 89) which must be installed in every case.

Section 147.—Parking Space Limits

The marking of parking space limits on urban streets tends to prevent encroachment on fire hydrant zones, bus stops, loading zones, approaches to corners, and clearance spaces for islands. Such parking space limits may be indicated on the pavement by lines marked perpendicular to the curb and extending into the roadway the width required by a parked vehicle, usually 7 feet. As a further refinement a line may be placed parallel to the curb connecting the street ends of these perpendicular lines, indicating the outside boundary of the parking zone. The zone may be divided into stalls by the use of lines perpendicular to the curb and so spaced that each stall is long enough to accommodate one parked vehicle, usually 20 feet. In this case a short line, parallel to the curb, may be placed at the end of each stall line, in place of the continuous line extending the length of the parking zone (fig. 17).

The marking of stalls is especially beneficial where parking meters are used.

Angle parking is generally not desirable, though occasionally it may be justified as, for example, on an unusually wide pavement where passing traffic is light and relatively slow moving. Where angle parking is permitted the marking of lines to indicate the limits of stalls enables all drivers to park at the same angle with a minimum of waste space.



The transverse spread of the "X" may vary according to lane width. A three-lane roadway should be marked with a center line for two-lane operation on the approach to a crossing. On a four-lane road the transverse bands should extend across the two right-hand lanes only to the center line, and a 10-foot "X" should be centered in the right half of the pavement. On roadways where one half the pavement width (or the width assigned to traffic in one direction) exceeds 30 feet, two or more of the $\overline{X}$ symbols should be symmetrically placed side by side on the right half of the pavement.

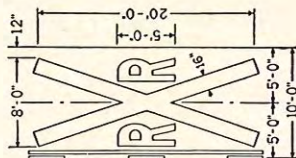


Figure 18.—Standard pavement markings at railroad crossings.

All lines for parking spaces shall be solid white lines, not less than 4 nor more than 6 inches wide.

Section 148.—Word Markings

Word markings on the pavement may be used for the purpose of guiding, warning, or regulating traffic. They should be limited to as few words as possible, never more than three.

Word markings shall not be used for mandatory messages except in support of standard signs. They shall be white in color.

The letters should be greatly elongated in the direction of traffic movement because of the low angle at which they are viewed by approaching drivers. One method of designing elongated letters and numerals is illustrated in figure 19.

On high-speed roads, especially where traffic is heavy, messages of more than one line are undesirable and should generally be avoided. It is difficult to read and understand a message when the words are necessarily spread over so great a distance that they are not all legible at one time.

Where prevailing traffic speeds are greater than 35 miles per hour large letters and numerals should be used, 8 feet or more in height; and, if the message consists of more than one word, it should read "up," i. e., the first word should be nearest the driver. The space between lines should be at least four times the height of the characters.

On the other hand, where prevailing traffic speeds are 35 miles per hour or less, it is possible to use smaller letters and numerals, and to space the lines closer together so that an entire message of as many as three lines may be seen and read at one time. In this case, a message of two or three lines should be arranged to read "down," i. e., with the first word farthest from the driver. The spacing between the lines should be equal to the height of the characters.

The word STOP shall never be used on the pavement in advance of a Stop line, unless every vehicle is required to stop at all times.

Figures 3, 16, and 17 show uses of word markings on the pavement.

Section 149.—Curb Markings for Parking Restrictions

Curb markings may be used to show where parking is prohibited at all times. They should not be used except on curbs along which parking is legally prohibited, either by general ordinance, as at fire hydrants, adjacent to corners, and opposite loading islands, or by the erection of standard no-parking signs.

The curb marking shall be of a solid yellow color, covering the face and top of the curb.

Experience has shown that the public does not easily understand a color code where several colors are used in curb marking to indicate different types or degrees of parking restrictions. Curb markings are accordingly recommended only to show that parking is prohibited at all times. Other restrictions should be shown by standard parking signs.

C—OBJECT MARKINGS

Section 150.—Application of Object Markings

Physical obstructions in or near a roadway that constitute serious hazards to traffic, including installations designed for the control of traffic, shall be adequately marked.

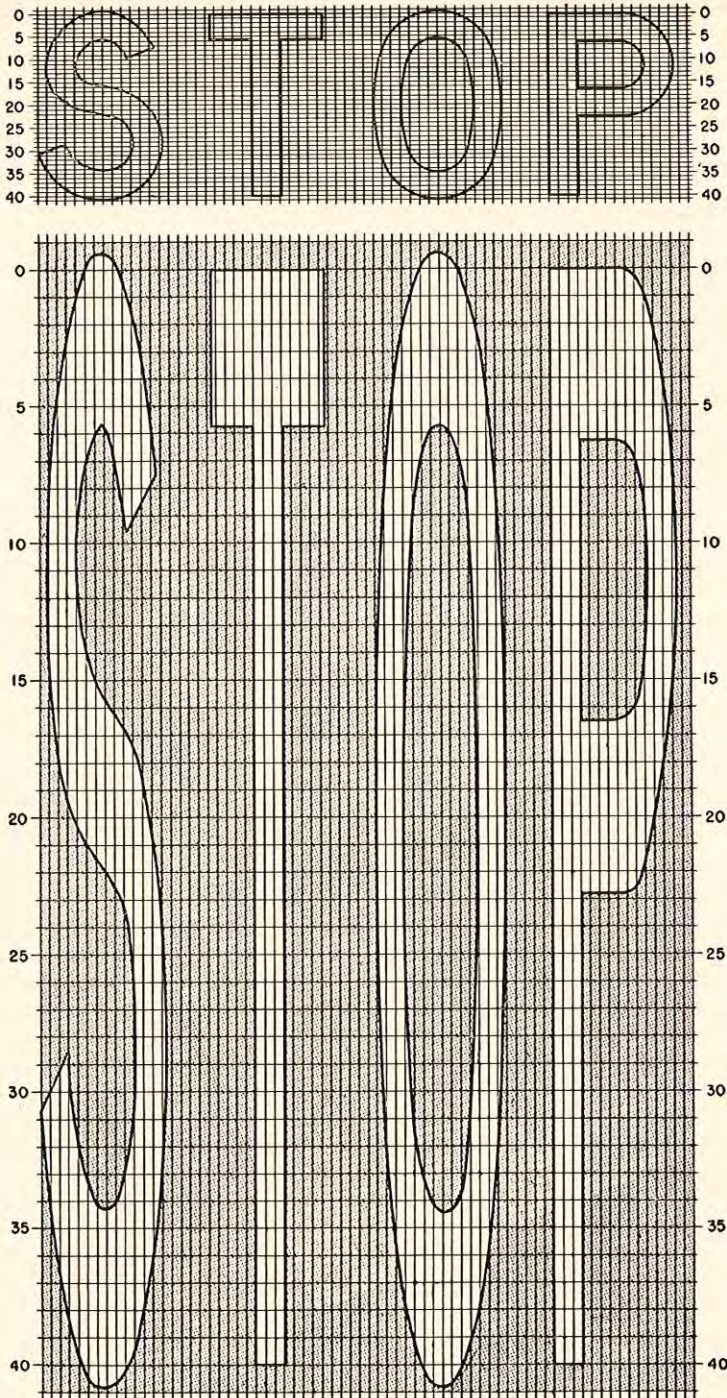


Figure 19.—Method of developing elongated letters for pavement markings.

Typical obstructions of this character are bridge supports, monuments, traffic islands, beacon or signal supports, loading islands, barricades to close roads, railroad and drawbridge gates, end posts of narrow bridges, underpass piers and abutments, culvert head walls, guard rails, sign posts, poles, trees, and rocks, and structures giving restricted overhead clearance.

Only such immovable obstructions as bridge supports and necessary islands should be permitted to remain within the roadway. Even at the present time, obstructions are occasionally placed in roadways under the mistaken belief that they will serve as aids to the control of traffic. Such installations include signal pedestals in the center of intersections, sign or signal posts at railroad crossings, and large "mushroom" buttons in active traffic areas. These should invariably be removed for safety.

Judgment must be exercised in the marking of objects off the roadway but it may be noted that, even where they are theoretically at a safe distance from the roadway, marking them may prevent serious accidents and facilitate night driving.

Section 151.—Objects Within the Roadway

Obstructions in the roadway shall be marked with not less than five alternating black and white stripes. The stripes shall slope downward at an angle of 45 degrees toward the side of the obstruction on which traffic shall pass. The alternate stripes shall be uniform and not less than 4 inches in width. They may be as much wider as may be necessary to make a good appearance and to provide sufficient visibility, depending on the size of the object and speed of approaching traffic. Typical markings are illustrated in figures 1, 20, and 33.

A curb at the end of an island would not require stripes of more than the 4-inch minimum width, while a large surface, such as a bridge pier, might require stripes of 12-inch or greater width depending on its area. The wider stripes are easier and less expensive to apply.

If the obstructing object is such that it does not lend itself readily to the application of painted markings, the striping may be placed on an independent surface attached to or mounted immediately in advance of the object.

Appropriate signs (R-14, W-30; secs. 42, 86) directing traffic to one or both sides of the obstruction should also be used, as applicable.

In addition to the markings on the face of an obstruction in the roadway, warning of approach to the hazard shall be given by line markings on the pavement, as prescribed in section 139.

Section 152.—Lighting or Reflectorization of Obstructions

Where an obstruction lies in the direct line of traffic, the obstruction and markings thereon should, if possible, be illuminated by a floodlight so constructed that it will adequately light the object but will not throw a glare in the face of traffic approaching from either direction. When floodlighting is not practical, the object markings should be effectively reflectorized. A reflecting coating should be applied to the white stripes or there should be placed on the obstruction one or more large yellow reflectors or clusters of yellow reflecting buttons at least 10 inches in diameter.

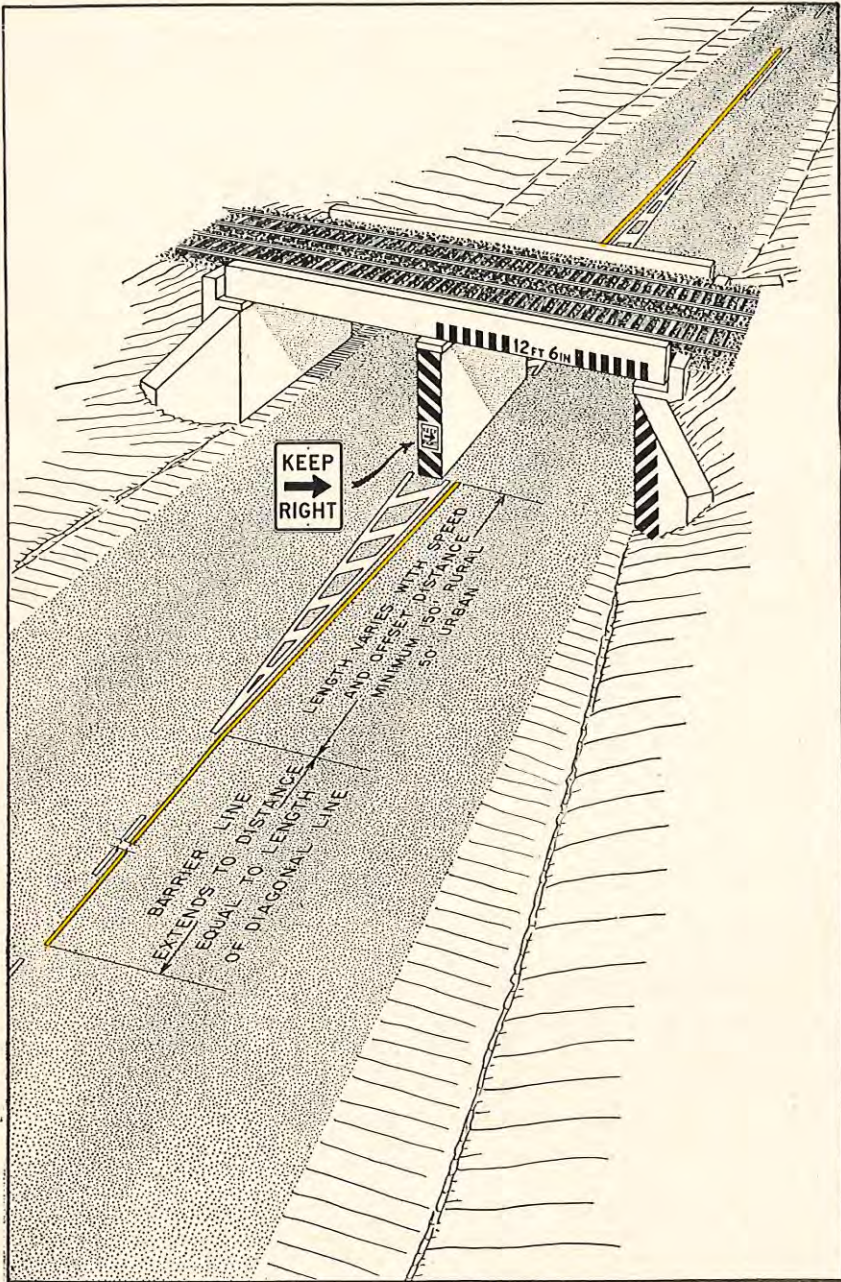


Figure 20.—Typical markings on objects in and adjacent to the roadway.

Section 153.—Object Markings on Curbs

Alternate black and white stripes should be placed on the curbs of all islands located in the line of traffic flow. They may also be helpful on curbs directly ahead of traffic at T and offset intersections. Because of the ordinarily low height of curbs, the stripes should be vertical on the curb face, rather than sloping as on other obstructions (fig. 40).

Where the curb is naturally dark, sufficient contrast may be obtained by painting only the white stripes.

Section 154.—Objects Adjacent to the Roadway

In some cases objects may not be actually in the roadway, but may be so close to the edge of the roadway as to constitute a definite hazard. These include such encroachments as underpass piers and abutments, and culvert head walls. They should be marked with the diagonal stripe design described in section 151.

Other adjacent objects that are not likely to be hit unless a vehicle runs well off the roadway, such as guardrails, trees, and rocks, may be painted solid white.

D—REFLECTOR MARKERS**Section 155.—Application of Reflector Markers**

Reflector markers, consisting of single reflecting buttons, clusters of buttons, small panels covered with reflecting coatings, or similar devices, are widely used in marking obstructions and other hazards, or, in series, to indicate alinement of the road. In the latter application they are known as Delineators. Although, like signs, such reflecting units are mounted on posts and convey a warning to the driver, they are much more closely related to obstruction markings or guide lines, and for the purposes of this manual are treated as such.

Section 156.—Hazard Markers

Reflector markers may be mounted on or immediately in advance of obstructions, or at sharp changes in alinement, to indicate the presence of hazards. Hazard Markers should be of such design as to be clearly visible under ordinary atmospheric conditions from a distance of 500 feet when illuminated by the upper beam of standard automobile headlamps.

Hazard Markers should reflect yellow light. They should be mounted at a height of approximately $3\frac{1}{2}$ feet above the pavement, except when they are applied directly to a hazardous object which by its nature requires higher or lower mounting, such as a limited overhead clearance or a low culvert head wall.

Single small reflector buttons are not ordinarily effective as Hazard Markers. Clusters of buttons arranged in suitable patterns, small plates covered with reflecting coatings, or other units of characteristic design should be used. No single standardized design has been developed for these markers. Since their meaning is nonspecific, however, the important thing is that they be large enough and brilliant enough for clear visibility. For obstructions closely adjacent to the roadway, markers having three $1\frac{1}{2}$ -inch buttons arranged vertically, or their equivalent, are recommended. For obstructions within the

roadway larger clusters or reflecting areas up to 12 inches in diameter may be desirable. Similar large units may be used at the end of a dead-end street, directly ahead of traffic at a T intersection, or on the outside of an unexpectedly sharp turn. On overhead structures, or on curbs in the line of traffic, rows of buttons, suitably spaced, or strips of reflectorized coatings may be used. Standard signs (R-14, W-11, W-30; secs. 42, 68, 86) should also be used, where applicable.

Section 157.—Delineators

Road-delineation markers are effective aids for night driving. Delineators are to be considered as guide markings rather than warning devices. They may be used on long continuous sections of highway or through short stretches where there are changes in vertical or horizontal alinement, particularly where the alinement might be confusing. An important advantage of Delineators, in certain areas, is that they remain visible when there is snow on the ground.

Delineators shall consist of reflector units mounted on suitable supports, the units being capable of reflecting light of the same color as that of the source and being clearly visible under normal atmospheric conditions from a distance of 1,000 feet when illuminated by the upper beam of standard automobile headlamps. The heads or reflector units shall be not more than 3 inches wide and 10 inches high nor less than 2 inches wide and 6 inches high. The reflectorizing elements or surface may consist of glass or plastic buttons, a glass-bead reflecting coating, or other suitable reflecting material.

When used on long continuous sections of undivided roadway, bidirectional Delineators (i. e., Delineators with two faces, visible from opposite directions, or two Delineators mounted back to back) shall be installed on both sides of the roadway. When used on divided roadways and at certain isolated locations such as pavement-width transitions not included in a continuous delineated section of highway, monodirectional delineators shall be installed. On divided roadways such monodirectional delineators shall be used on both sides of each roadway. At isolated pavement-width transitions they shall be used only on that side of the roadway affected by such a transition.

Delineators shall be installed at a height such that the center of the reflecting head is $3\frac{1}{2}$ feet above the near pavement or roadway edge. They shall in no case be more than 10 feet nor less than 2 feet outside the roadway or pavement edge, the most desirable location being uniformly 8 feet, leaving a clear shoulder wide enough for the parking of a vehicle. On roadways with shoulders less than 8 feet wide, Delineators, if used, shall be installed at the shoulder edge. Along curbed sections of roadway, Delineators, if used, shall be placed not less than 2 feet nor more than 5 feet from the curb face.

Normally, Delineators should be spaced 200 feet apart. Where such spacing is interrupted by driveways, crossroads, etc., and where, under the normal spacing, a Delineator would fall within such an area, that Delineator may be moved in either direction a distance not exceeding one quarter of the normal spacing. If such Delineator still falls within that area, it should be eliminated.

On the approaches to and throughout horizontal curves the spacing

should be such as to make five Delineators always visible to the right of the center line of a two-lane pavement, or of the right-hand lane line of a multi-laned pavement. Table 1 shows the recommended spacing for horizontal curves.

The recommended spacing for vertical curves is shown in table 2.

Table 1.—Spacing ¹ for highway delineators on horizontal curves

Degree of curve	Spacing on curve	Spacing in advance of and beyond curve		
		First space	Second space	Third space
	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>
1.....	91	164	200	200
3.....	53	95	159	200
5.....	41	75	123	200
7.....	35	63	105	200
9.....	31	56	93	186
12.....	27	49	81	162
15.....	24	43	72	144
18.....	22	40	66	132
21.....	20	36	60	120
25.....	19	34	57	114
30.....	17	31	51	102

¹ The spacing, S , on the curve is found from the formula $S=1.2\sqrt{R+18}$, where R is the radius of the curve in feet. The spacing to the first delineator in advance of and beyond the curve is $1.8S$, to the next delineator $3S$, and to the next $6S$, but not to exceed 200 feet.

Table 2.—Spacing ¹ for highway delineators on vertical curves (summits)

Algebraic difference in percent of grade	Delineator spacing, in feet, when length of vertical curve is—												
	100	200	300	400	500	600	800	1,000	1,200	1,400	1,600	1,800	2,000
0.5.....	113	168	200	200	200	200	200	200	200	200	200	200	200
1.0.....	74	113	143	168	190	200	200	200	200	200	200	200	200
1.5.....	57	89	113	134	152	168	197	200	200	200	200	200	200
2.0.....	46	74	95	113	129	143	168	190	200	200	200	200	200
2.5.....	39	64	83	99	113	126	148	168	186	200	200	200	200
3.0.....	34	57	74	89	101	113	134	152	168	183	197	200	200
4.0.....	27	46	61	74	85	95	113	129	143	156	168	179	190
5.0.....	22	39	53	64	74	83	99	113	126	137	148	158	168
6.0.....	19	34	46	57	66	74	89	101	113	124	134	143	152
7.0.....	17	30	42	51	59	67	80	92	103	113	122	131	139
9.5.....	13	23	33	41	48	55	66	76	86	94	102	109	116
12.0.....	10	18	27	34	41	46	57	66	74	82	89	95	101
14.5.....	8	14	23	29	35	40	50	58	66	72	79	85	90
17.0.....	7	12	20	26	31	36	44	52	59	65	71	77	82
19.5.....	6	11	18	23	28	32	40	47	54	60	65	70	75
24.0.....	5	10	16	21	25	29	34	41	46	52	57	61	66

¹ The spacing, S , on the vertical curve (to a maximum of 200 feet) is found from the formula: $S=94\sqrt{\frac{L}{G}}-20$ where L is the length of curve in hundreds of feet and G is the algebraic difference in percent of grade. The spacing to the first delineator in advance of and beyond the curve should be $1.8S$, to the next delineator $3S$ and to the next $6S$, but not to exceed 200 feet.

Part III

SIGNALS

A—INTRODUCTION**Section 158.—Definitions**

Highway traffic signals include all power-operated traffic control devices, except signs, by which traffic is warned or is directed to take some specific action. A glossary of traffic signal terms will be found in appendix A.

Section 159.—Value of Signals

The traffic signal is a valuable device for the control and safe facilitation of vehicle and pedestrian traffic. Because of its arbitrary or traffic-induced assignment of right-of-way to the various movements necessary at intersections and at other street and highway locations, the traffic signal exerts a profound influence on traffic flow. In most cases, a signal installation will operate quite definitely either to the advantage or disadvantage of the vehicles and persons controlled. Consequently, it is of the utmost importance that the selection and use of such an important control device be preceded by thorough study of roadway and traffic conditions by an experienced engineer. Equally urgent is the need for checking the efficiency of a traffic signal, once in operation, to ascertain the degree to which the type of installation and the timing program meet the requirements of traffic, and to permit intelligent operating adjustments to be made in the controls. Checkbacks are of value not only to the particular installation concerned but in the selection of proper equipment and operating plans for future installations as well.

Highway traffic signals, properly operated, usually have one or more of the following advantages:

1. They provide for orderly movement of traffic.
2. They reduce the frequency of certain types of accidents.
3. They can be coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route.
4. They can be used to control speed on through highways and main routes.
5. They can be used to interrupt heavy traffic at intervals to permit other traffic, pedestrian or vehicular, to cross.
6. They represent a considerable economy, as compared with manual control, at intersections where some definite means of assigning right-of-way first to one movement and then to another is required by the volumes of vehicular and pedestrian traffic, or by accident conditions.

There is a belief among laymen and some engineers that traffic signals are the answer to all traffic problems at intersections. This has led to their installation at a large number of locations where no legitimate factual warrant exists. This stereotype plan of installation should be avoided.

Many signal installations, even though warranted by traffic and

roadway conditions, have been ill-designed, ineffectively placed, improperly operated, or poorly maintained. The consequences have often been excessive delay, disobedience of signal indications, use of alternate routes, and, often, increased accident frequency. The same difficulties are often found when signals have been installed under conditions that do not satisfy the minimum warrants set forth later on in this manual.

A careful analysis of conditions at a large number of traffic signal installations, coupled with the judgment of engineers with long experience in the signal field, has provided a series of minimum warrants that define the conditions under which a traffic signal installation may be justified. These warrants are presented in this manual for the several signal classifications.

Separate values are given for warrants for rural and urban areas, in recognition of differences in the nature and environment of traffic in these two general area classes. Drivers in rural areas are conditioned to relatively light traffic, and intersections with only moderately heavy traffic volumes have greater potentials in terms of congestion and hazard than do similar intersections within a city area where heavier volumes predominate. An urban area is here considered to be a metropolitan region having a population of 5,000 or more. All other places, for the purpose of these warrants, are regarded as rural areas.

Section 160.—Standardization

Because of the increasing range of traffic circulation, it is of primary importance that there be national standardization of those features of traffic signals that affect public participation in traffic movement. Design, application, location, and operation all lend themselves to a certain degree of standardization, and standards for such features are presented herein.

The increasing use of and need for train-approach signals and automatic gates at railroad grade crossings heighten the importance of standardization of this type of equipment. The principal features of design and operation that have been standardized by the Association of American Railroads are set forth in the portions of the text dealing with train-approach signals.

Section 161.—Legal Authority

Traffic signal indications would be unenforceable if placed by other than public authority. Unofficial traffic signals should be legally prohibited in all jurisdictions. The erection of signs or other devices that hide from view to interfere with the effectiveness of any traffic signal should likewise be prohibited. It is imperative that traffic signal indications be strictly observed and enforced. Suitable legislative models covering these points are presented in Act V of the Uniform Vehicle Code (art. III) and in the Model Traffic Ordinance (art. IV). The Code and the Ordinance authorize the State highway commission and the city traffic engineer, or similar public officials or bodies, to place and maintain a uniform system of traffic control devices correlated with, and, so far as possible, conforming to the system currently approved by the American Association of State Highway Officials. When this broad control is properly exercised,

the full value of standardization in traffic signal design and installation can be realized.

Section 162.—Classification

In the classification of traffic signals that follows, the distinction is made on the basis of operating function and not the traffic signal unit itself. It is common practice to use the term "signal" to describe the complete installation, and that practice will be followed in this manual.

Highway traffic signals are classified as follows:

1. Traffic control signals (Stop-and-Go) :
 - (a) Fixed-time signals (secs. 205-232).
 - (b) Traffic-actuated signals (secs. 233-268) :
 - (1) Full traffic-actuated signals.
 - (2) Semi-traffic-actuated signals.
 - (3) Speed control signals.
2. Special pedestrian signals (secs. 269-276).
3. Other special traffic signals :
 - (a) Flashing beacons and signals (secs. 278-283).
 - (b) Lane-direction traffic signals (secs. 284-289).
 - (c) Traffic signals at drawbridges (secs. 290-294).
4. Train-approach signals and gates (secs. 295-311) :
 - (a) Flashing light and wigwag signals.
 - (b) Automatic crossing gates.

B—FEATURES COMMON TO FIXED-TIME AND TRAFFIC-ACTUATED SIGNALS

Section 163.—General Aspects of Signals

The features of traffic control signals in which vehicle operators and pedestrians are interested, namely, the location, design, indications, and legal significance of the signals themselves, are identical in fixed-time and traffic-actuated signals, the difference between the two types being in the mechanisms that operate them. Standardization in those design factors that affect the traffic to be controlled is especially important. The sections of this subdivision contain all standards and requirements of this nature that are equally applicable to the two types of signals named. Standards applicable to but one type, including design features and methods of operation, are presented in subsequent subdivisions.

Section 164.—Design for Future Needs

Traffic control equipment should always be purchased with the future in mind. Flexibility which may not immediately be considered necessary will often be found desirable within the life of the equipment. Equipment that will give long effective life will almost always prove an economy even if the first cost is moderately higher than that of equipment of inferior quality.

Section 165.—Number of Lenses per Signal Face

Each signal face shall have at least three lenses—red, yellow, and green. It may have additional lenses as indicated herein.

Experience has shown that the yellow indication serves several important traffic control functions that cannot satisfactorily be served by a two-lens signal face. These are:

1. The yellow signal acts as a cushion at the end of the Go interval and warns approaching traffic of a change in signal indication.
2. Cars within an intersection or other signalized area, as well as those ap-

proaching so closely that to stop would be hazardous, are given an opportunity to clear.

3. Flashing yellow is important as a caution signal when the signal is not being operated as a Stop-and-Go device.

Arrow indications shall be shown at intersections where signals for individual turning movements are provided. These include:

1. Straight-through arrow.
2. Left-turn arrow.
3. Right-turn arrow.

Lenses for the control of pedestrians may also be added to each signal face, as specified in sections 272 to 274.

Section 166.—Color and Position of Lenses

All lenses shall be arranged in a straight and preferably vertical line and shall be in the following order, from top to bottom or from left to right:

Position :	Signal indication
1-----	Red
2-----	Yellow
3-----	Green
4-----	Straight-through arrow
5-----	Left-turn arrow
6-----	Right-turn arrow
7-----	Wait (or Don't Walk)
8-----	Walk

All arrows shall be green on an opaque background. Walk-Wait lenses which are incorporated in standard signal faces shall be of the design described in section 272.

The colors red, yellow, and green shall conform to the adjustable-face traffic control signal head standards of the Institute of Traffic Engineers,⁴ approved as an American Standard by the American Standards Association (D-10.1-1942).

In addition to the foregoing lenses, special pedestrian signals mounted apart from the traffic signal head may be provided as specified in sections 272 and 274.

Section 167.—Meaning of Color and Arrow Indications

Color and arrow indications in traffic control signals should have the meanings ascribed to them in this section and no other meanings. In no case, however, should a driver be permitted to enter or proceed through an intersection without due regard for the safety of other persons within the intersection, regardless of signal indications.

Satisfactory results from traffic signal operation require a uniform understanding of their color indications. Those herein set forth are in accord with Act V of the Uniform Vehicle Code (secs. 34, 36). The simultaneous illumination or overlapping of different color indications, except where green arrows are shown together with the circular red indication, or where pedestrian lenses are involved, is not recommended.

This section applies primarily to traffic control signals at intersections, but appropriate interpretation can be readily made for use

⁴ *Adjustable Face Traffic Control Signal Head Standards*, Technical Report No. 1, Institute of Traffic Engineers.

of signals elsewhere, such as at school crossings, fire stations, and drawbridges.

The meanings of the indications, which should be thus prescribed by law, are as follows:

Green (alone):

1. Vehicular traffic facing the signal, except when prohibited by a superior regulation, may proceed straight through or turn right or left unless a sign at such place prohibits either such turn. But vehicular traffic, including vehicles turning right or left, shall yield the right-of-way to other vehicles and to pedestrians lawfully within the intersection or an adjacent cross walk at the time such signal is exhibited.

2. Pedestrians facing the signal may proceed across the roadway within any marked or unmarked cross walk unless directed otherwise by a pedestrian signal.

Yellow (alone, following green):

1. Vehicular traffic facing the signal is thereby warned that the red or Stop signal will be exhibited immediately thereafter, and such vehicular traffic shall not enter or be crossing the intersection when the red or Stop signal is exhibited.

2. Pedestrians facing such signal are thereby advised that there is insufficient time to cross the roadway, and any pedestrian then starting to cross shall yield the right-of-way to all vehicles.

The yellow lens is required in standard signal apparatus for the reasons indicated in section 165. Confusion has frequently arisen from the misuse of this lens. When the length of yellow vehicle-clearance interval is correct, and the standard meaning above described is generally observed, necessary functions of warning and clearing the intersection are performed by this interval.

Red (alone):

1. Vehicular traffic facing the signal shall stop before entering the cross walk on the near side of the intersection or, if none, then before entering the intersection, and shall remain standing until a green signal is shown.

2. No pedestrian facing such signal shall enter the roadway unless he can do so safely and without interfering with any vehicular traffic or unless a separate Walk indication is shown.

Confusion and serious hazard result from lack of uniform obedience to red signals. The red indication should always mean that each vehicle shall stop and shall not proceed farther until a Go signal appears, unless specifically authorized by one of the auxiliary indications described below.

Red with green arrow:

1. Vehicular traffic facing such signal may cautiously enter the intersection only to make the movement indicated by such arrow, but shall yield the right-of-way to pedestrians lawfully within a cross walk and to other traffic lawfully using the intersection.

2. No pedestrian facing such signal shall enter the roadway unless he can safely and without interfering with any vehicular traffic, or unless a separate Walk indication is shown.

Permitting vehicle operators to make right or left turns during the showing of the red signal without a modifying arrow is bad practice. It weakens the single meaning of the red indication. The practice cannot be permitted at all intersections, and, therefore, cannot be followed uniformly. It adds to pedestrian hazards and inconvenience, and creates hazards and delays for vehicle movement.

The appropriateness of right and left turns proceeding during the Stop period is exceptional and therefore these movements, when necessary, deserve a specific modifying indication, as is provided by the right- or left-turning arrow lens. If such turning arrows are shown

when through movement is stopped, they should always be illuminated in conjunction with the red signal they modify. Shown alone, they create doubt as to whether other movements are forbidden during the indicated interval. Furthermore, drivers approaching an arrow indication may mistake it for the customary Go signal. This is especially likely where strange drivers are involved and where the arrow signal is poorly designed.

The utility of arrow indications depends considerably upon there being a lane consistently available for the movement indicated. Such lanes should be clearly marked on the roadway surface at all times.

A circular green indication shall be given only when it is intended to permit traffic to proceed straight ahead or turn in either direction. Whenever it is intended to permit traffic on a certain thoroughfare to make certain movements and prohibit it from making others, the regular circular red lens facing that traffic shall be illuminated together with a separate green arrow for each permitted movement.

The foregoing is not intended to prevent prohibition of turns, at all times or during certain periods of the day, by the erection of signs.

The plan has been tried of prohibiting certain movements, such as a left turn, on the regular circular green indication by signs stating that those movements are allowed only on separate green arrow indications. This has not been satisfactory, however, because drivers fail to comprehend the apparent conflict in instructions and proceed to make the prohibited turn on the circular green indication.

Flashing red (Stop signal) :

When a red lens is illuminated by rapid intermittent flashes, drivers of vehicles shall stop before entering the nearest cross walk at an intersection or at a Stop line when marked, and the right to proceed shall be subject to the rules applicable after making a stop at a Stop sign.

In some jurisdictions there may be need for introduction of legislation to define the meaning of the flashing red indication so that Stop signs will not have to be used when signals are on flashing red for part of the day.

Flashing yellow (caution signal) :

When a yellow lens is illuminated with rapid intermittent flashes, drivers of vehicles may proceed through the intersection or past such signal only with caution.

The use of steady yellow as a caution signal is not recommended.

Section 168.—Shapes and Dimensions of Lenses

Traffic control signal lenses shall be circular with a visible diameter of not less than 8 inches.

A green arrow lens shall show an arrow so designed that its shape will be distinctly visible at a distance of 200 feet. An arrow to indicate straight-through movement shall be pointed vertically upward, and an arrow to indicate substantially a right-angle turn shall be horizontal.

Where the turn is substantially different from a right angle, the arrow may be pointed obliquely upward on a slope appropriate to the angle of the turn.

It is essential that approaching drivers be able to recognize the green arrow shape at a sufficient distance to govern their actions accordingly. Some arrow lenses now in use fail to meet this requirement

and should be replaced with properly designed lenses as promptly as possible. Figure 21 shows the details of an arrow lens design developed by the Committee on Standards of the Institute of Traffic Engineers from numerous field tests under both day and night conditions.

Section 169.—Lettering on Lenses

Lettering shall not be used on lenses. This does not apply to special pedestrian signals (sec. 272).

The practice of embossing GO on green lenses, CAUTION on yellow lenses and STOP on red lenses reduces the effectiveness of the lenses. With the spread of uniform meanings and positions, the need for such lettering is constantly decreasing.

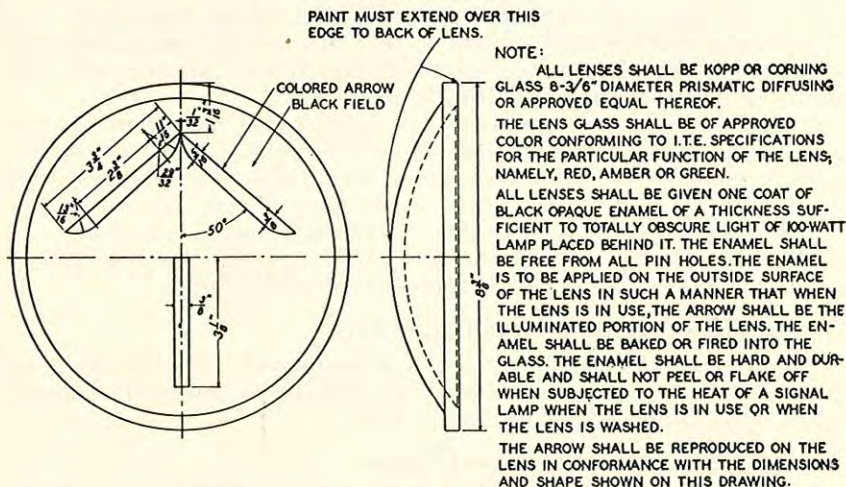


Figure 21.—Arrow lens design; Institute of Traffic Engineers.

Section 170.—Illumination of Lens

Each lens shall be illuminated independently of any other lens. The illumination shall be by a clear lamp of not less than 40-watt capacity, especially designed for traffic signals.

This provision is not intended to preclude the use of other properly designed light sources, such as those utilizing gaseous mixtures, which produce an equally effective signal lens indication.

Independent illumination of each lens is essential to permit uniform position of lenses, give satisfactory brilliance, and provide the necessary flexibility in signal indications. Special lamps with sturdy filaments and other appropriate characteristics have been designed to meet traffic signal requirements. A 60-watt lamp has been most generally used, but 67-watt and 40-watt traffic signal lamps are also available.

The 40-watt lamps are economical in current consumption but should be used only when the lens transmission factor is sufficient to give a conspicuous indication and when there are no confusing background lights or sun glare.

For most effective indications, traffic control signal lamps should be operated at full voltage, rather than under voltage. When lamps

rated at a higher voltage than the actual voltage at the lamp socket are used, longer lamp life results, but at the expense of light output and signal brightness.

More desirable than the above practice is the use of higher wattage lamps which will give the equivalent light output with a longer life. To serve this purpose the 67-watt traffic signal lamp has been developed and made available. Though consuming slightly more power for an equivalent light output, its life has been considerably extended.

Section 171.—Visibility and Shielding of Lens

Each lens, reflector, and visor shall be of such design as to render the signal indication, when illuminated, clearly visible to the traffic controlled by that face at all distances from 10 to 300 feet, under all light and atmospheric conditions except dense fog.

Each signal face shall, to the extent practicable, be so shielded by visors or hoods that an approaching driver can see only the signal indications intended for his observance.

Confusion results if signals are so located that operators see two signal faces giving different indications. Irregular street design frequently necessitates so placing signals that there is a comparatively small angle between their beams. Such cases require especial care in shielding so that the driver will be sure which signal he is to obey.

Shielding also reduces the tendency of drivers who see the yellow indication on the cross street to "jump" the Go indication.

Section 172.—Auxiliary Illuminated Signs

Signal heads and auxiliary mounting equipment should be designed so that auxiliary signs can be attached and illuminated either above, below, or on either side of any signal face.

Section 173.—Number of Signal Faces

In rural areas there shall be one or more signal faces visible to traffic on each approach to the intersection, except in those cases where the minimum pedestrian volume warrant is met, when a minimum of two faces shall be used for each approach.

In urban areas there shall be two or more signal faces visible to traffic on each approach to the intersection.

The advantages of having at least two faces for each approach roadway are believed sufficient to warrant making this a general requirement in urban areas. Trucks and busses very frequently obscure one-face installations, leaving the drivers of vehicles immediately behind uncertain of the signal indication as they approach. Two properly located faces will, at practically all intersections, provide drivers with a signal indication sufficiently in advance to insure their proper reaction to conditions at the intersection. High speeds and other traffic considerations will frequently warrant the use of two signal faces even in rural areas.

The advantage to pedestrians alone justifies the installation of two signal faces at many locations, since it provides indications within reasonable range of the normal line of sight for all persons on foot. If one of the signal faces is to be on the near side, however, a total of three faces will be needed to provide adequate pedestrian indications. Satisfactory enforcement of pedestrian regulations is difficult unless signal faces are clearly visible for all lines of pedestrian movement.

Section 174.—Limit of Signal-Controlled Area

A signal shall control traffic only at the intersection where the installation is located.

Depending on signals at a few intersections to control traffic at intermediate nonsignalized intersections is an uncertain and hazardous practice. Under such conditions, drivers on cross streets at nonsignalized intersections must often enter the cross walk to see a signal indication on the main street. Strangers are likely to enter nonsignalized intersections unknowingly, which is obviously hazardous.

Section 175.—Location of Signal Faces at Intersections

Signal faces shall be located so as to give drivers and pedestrians a clear and unmistakable indication of the right-of-way assignment from their normal positions on the approaches and as they enter or pass through the intersection area. Where signals are installed on the basis of the pedestrian volume warrant, or where the pedestrian volume warrant is equalled or exceeded, a vehicle or pedestrian signal face shall be installed at the far end of each cross walk.

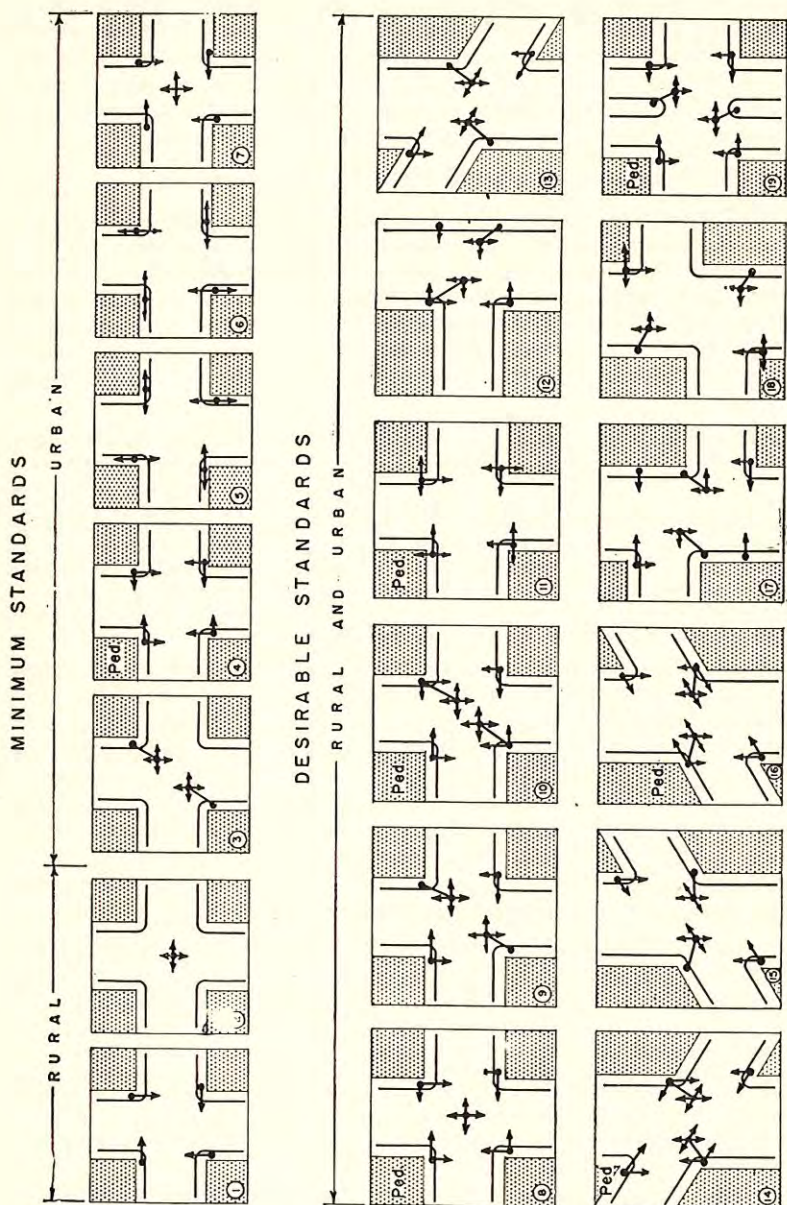
One of the more controversial points in the standardization of traffic signal practice has been the matter of signal-face location at intersections. The advantages of far-side, near-side, mast-arm, and center-suspended locations have been sufficient to induce the choice of all these locations for various types of situations, despite a definite endorsement in the previous manual of the far-right-corner location. When asked in a recent poll to express their preference as to signal location, a group of 36 outstanding traffic engineers could not develop a majority for their first choice for either rural or urban intersections, although the greatest number of votes was cast for the center-suspended location in rural areas and for the far-right—far-left location in urban areas.

Because of the diversity in practice and the lack of agreement among qualified engineers on signal location, the above requirement does not specifically fix the points of signal placement. Instead, the engineer is held responsible for a study of the visibility conditions on each intersection approach and the subsequent positioning of a signal indication conspicuously within the normal line of view of drivers and pedestrians using the intersection. Although this individualized selection of signal location seems the most desirable, undue variation in location from intersection to intersection along the same street is to be avoided, as this may create confusion and hazard.

The need for pedestrians to have a signal indication directly before them while proceeding through the intersection area suggests the advisability of having signal faces at the far side of the intersection. With all far-corner signals, two signal faces per corner will provide a signal at the end of each pedestrian cross walk, whereas three signal faces per corner are needed to accomplish the same results with one signal on the near-right corner. (See sketches in fig. 22.)

The near-side location has merit in that the signal can be placed at or near the Stop line, the point of obedience. The near-side location, in a general way, is also a more consistent and uniform position with respect to the approach lanes than is the far side, especially where irregular types and forms of intersections are involved.

The trend toward the use of signals suspended directly over the traveled way, either on mast arms or on a span wire, has been increasing in recent years. This location is especially effective at rural intersections where speeds are high and maximum prominence for signal indications to drivers is needed. Another factor contributing toward more frequent use of over-the-roadway signals is the growth



NOTE: Location standards marked "Ped" apply to intersections where pedestrian volumes equal or exceed the warrant values.

Figure 22.—Standards for traffic signal locations.

in brilliance and color of illuminated advertising signs in shopping areas. Where such background lighting is likely to be a serious hindrance to the effective display of traffic signal indications, consideration should be given to the mast-arm or suspended location for at least one of the signal-face locations.

Pedestals in the roadway to carry signals are driving hazards and are not recommended, despite their obvious advantage as conspicuous signal locations. This is not intended, however, to preclude the use of signals on pedestals or posts within the area of properly designed channelizing islands or in the median strip of divided roadways.

Where physical conditions prevent a vehicle driver from having a continuous view of at least one signal indication through the 300 feet immediately in advance of the Stop line, an auxiliary signal location shall be used to provide this visibility. If physical conditions make it impossible to provide any location which can be seen for 300 feet, a caution signal (sec. 278) or a Signals Ahead sign (sec. 70) shall be erected in a suitable position to warn approaching traffic.

Section 176.—Height of Signal Faces

The bottom of the housing of a signal face shall be not less than 8 feet nor more than 10 feet above the sidewalk or, if none, above the pavement grade of the center of the highway, except that where vehicles must pass under a signal housing, the height to the bottom of the housing shall be at least 14½ feet but not more than 15½ feet above the roadway surface.

Maximum visibility is the guiding principle in deciding signal height. Signal faces should be high enough not to be obstructed unnecessarily by passing vehicles and pedestrians. On the other hand, especially in urban territory, the signal faces should be low enough to be within easy range of the average pedestrian's and waiting motorist's eyes. Grades on approaching streets may be important factors in determining the most effective height.

The clearance required for signal housings mounted over the roadway is consistent with general highway requirements for overhead structures.

Section 177.—Pointing of Signal Faces

Each signal face shall be so adjusted vertically and horizontally that its beams will be of maximum effectiveness to the approaching traffic for which it is intended.

In general, signals should be pointed so as to have a maximum effectiveness in the usual position of approaching drivers at a distance from the Stop line equal to the average distance they would move while reacting to the Stop indication and stopping their vehicles. The influence of curves or grades should also be considered in the aiming of signals.

For an average urban intersection where the normal speed of approaching traffic is 25 miles per hour, the point of maximum effectiveness for aiming the signal would be at the height of a driver's eyes, about 6 feet to the right of the center line of the pavement and about 75 feet back from the Stop line.

Frequently poles on which signal faces are installed are not exactly vertical. Brackets or other mounting fixtures used should be of such a

design that it will be possible to adjust the signal face both horizontally and vertically through a considerable angle.

Section 178.—Location in Relation to Curb Line

Signal faces mounted at the roadside shall be located as near as practicable to the curb line of the street whose traffic they control. They should be about 3 feet from the cross walk of the intersecting street, or from the place where a cross walk would normally be located. A signal or its support should not obstruct the cross walk.

In order to present to the driver a maximum of effectiveness, a post or bracket-mounted signal face should be kept close to the curb line. However, for the protection of the equipment from damage by passing vehicles, it is not desirable that any part of the signal head extend within 1 foot of the curb line.

Section 179.—Location in Relation to the Pavement or Traveled Surface

Regardless of the street or highway cross-section design, a signal face shall not be more than 10 feet to the right of the pavement or traveled surface.

In the case of rural highways, the shoulder width may create a problem in signal location. So long as the signal face is not more than 10 feet to the right of the pavement and is not hidden by foliage or other sight obstructions, it should be satisfactorily visible. Experience indicates that signals mounted on posts near the curb in urban areas are generally effective although, with parking at the curb, the right side of approaching vehicles is normally about 12 feet laterally from such signals, which roughly corresponds with the distance specified above as a maximum. The vehicle operator usually gives his major attention straight ahead, and a signal indication more than 10 feet from the edge of the moving lane is not likely to receive proper attention.

This rule has important bearing on both first cost and maintenance outlay, for if a signal can be post-mounted within 10 feet of the improved surface, the advantages of low mounting height and simplified maintenance result. However, if the shoulder width or some similar condition requires that a mast-arm-mounted signal or a center-suspended signal be used, costs are increased, mounting height is greater, and maintenance is more difficult.

Section 180.—Removal of Confusing Advertising Lights

Act V of the Uniform Vehicle Code (sec. 37) prohibits the display of any unauthorized sign, signal, marking, or device which interferes with the effectiveness of any official traffic control device. The enactment of this provision is particularly important. If enforced it will, among other things, reduce the serious confusion caused by lights of a color and location similar to traffic control signals. The steps necessary to eliminate this sort of hazard are warranted.

Section 181.—Provision for Future Installation

Signals should always be installed so that future traffic growth and other later requirements can be as readily met as possible. Outmoded, worn-out equipment and materials constitute serious handicaps to extension or improvement of existing signal systems. The type of mounting selected, the choice of wiring and accessory equipment, and

other seemingly minor details of a signal installation play an important part in the reliability and effectiveness of signal operation during their service period. These elements should be carefully chosen for the particular duty they are intended to perform, and with a view toward obtaining uniformity and standardization of equipment, so that exchange and replacement operations will be simplified.

Section 182.—Types of Mounting for Signal Heads

Types of signal-head mountings include the following:

1. Alongside the roadway:
 - (a) Posts 8 to 10 feet high.
 - (b) Short brackets attached to poles (at same heights).
2. Over or in the roadway:
 - (a) Long brackets or mast arms extending from poles off the roadway.
 - (b) Cable suspension.
 - (c) Posts or pedestals on islands.

Group 1 has many advantages, including simplicity of design, ease of access and maintenance, and better conformity in height to the needs of traffic. Of the two types in this group, post mountings are preferable. Where an existing pole is at the position desired for the signal faces, however, it is generally used. New poles may be installed to provide necessary support and clearance for overhead cable.

Mast-arm and cable suspension involve considerable lateral strain. Cable suspension may interfere with fire fighting and requires overhead maintenance equipment. Both of these types involve difficulties in cleaning and maintenance, besides placing the signals too high for best visibility to waiting traffic and to operators of vehicles close to the intersection. Suspended signals are desirable, however, at locations where side-mounted signals are apt to be overlooked, as at isolated rural intersections; where high-speed routes enter built-up areas; or where advertising signs and other distracting lights interfere with visibility of signals mounted along the roadway. To improve the effectiveness of the signal indications to waiting vehicles and pedestrians, post-mounted signals may be used to supplement overhead installations at such locations.

Signals on posts or pedestals on islands are justifiable only in certain large, channelized, or irregular intersections. Under these conditions, the signals should be well protected by properly designed islands and signs and by night illumination.

Any mounting should be substantially constructed, with a strong foundation, preferably concrete, and should be able to withstand all weather conditions.

Section 183.—Installation of Underground Conduit or Cable

Underground conduit or cable, though considerably more expensive than overhead wiring, is generally preferable, especially for urban intersections. In certain zones it may be legally required.

Before the underground wiring is installed, governmental units and utilities that may have underground structures or facilities at the location or may later place them there should be consulted. Much trouble and possible damages may thus be avoided. Furthermore, such organizations can give valuable advice as to how such work should best be done.

A large proportion of the cost of underground installations can be avoided if traffic control conduit is installed when the intersection or

signal location is torn up for some other purpose, such as for paving, repairing, or utility underground installations. Local authorities should anticipate future signal requirements and take advantage of any such opportunities to install conduit, even if such installation is in advance of the need. Though conduit is normally used, direct burial or "parkway" cable has also been employed successfully.

Section 184.—Selection of Cable

The cable is an important element in the successful and economical operation of a signal system.

Quality.—Experience has proved the desirability of using cable of high quality for all but purely temporary installations.

Some good traffic signal cable specifications (for use on 110–120 volt service) call for a 600-volt cable with at least three sixty-fourths of an inch of 30 percent para rubber insulation and good quality cloth-braid covering on each conductor and with a cable covering suitable for the intended use of the cable. Developments of the last few years have provided several other satisfactory types of cable, for which specifications are obtainable from cable manufacturers. No. 12 or No. 14 B. & S. gage wire is often used at intersections. The size of conductor required for a master control cable in a coordinated system should be computed.

Color code.—A standard color code should be adopted for traffic control cables. Such a code identifies each conductor with a particular color or combination of colors in its braid covering, according to the function served by that conductor.

The advantages of a standard color code are considerable. Any person familiar with the color code can install, test, or replace controllers quickly because the function accompanying each color scheme is known. Color coding generally eliminates the need of tagging the leads. One of the difficulties with tags or numbered bands is that they are likely to come off.

Spare.—It is generally sound economy to provide several spare conductors in each local interconnecting and master control cable. From time to time, for one reason or another, conductors in a cable may develop defects and be no longer suitable for use. In such cases, the provision of spare conductors eliminates the cost of locating the trouble and making repairs, or of installing new cable. Spare conductors also permit adding new features, such as a pedestrian clearance period, or an illuminated sign.

Section 185.—Insulation of Cable

Adequate cable insulation shall be provided throughout the entire installation, conforming to fire underwriters' specifications.

Section 186.—Cable Positions and Clearances

Positions for traffic control cables shall be such as not to interfere with utility structures and wires or with positions reserved for them. Suitable clearances agreed upon by all interested parties shall be provided in all cases.

In most communities the utility companies and appropriate governmental agencies have agreed upon certain positions on poles and certain positions underground for various structures, conduits, and wires.

Much trouble can be avoided if those in charge of traffic signal installation will consult with the affected groups concerning location problems. Where a pole is used for several types of cable it is most important to maintain clearances satisfactory to all parties involved.

Section 187.—Messenger Wires

All overhead cable shall be supported by a suitable aerial messenger wire whenever there is a span of more than 30 feet.

The use of aerial messenger wire in such cases removes the strain from signal cables, and reduces the likelihood of cable trouble. Unsupported cable is apt to develop trouble at the ends of cable spans.

It is good economy to provide high-grade aerial messenger wire, such as that with a copper covering welded to the steel by the molten welding process. The size and strength of messenger wire depends on the load to be carried, but five-sixteenths-inch wire with an ultimate strength of not less than 6,200 pounds is usually satisfactory for a 12-conductor signal cable.

Section 188.—Efficiency and Continuity of Operation

The full utility of traffic signals is realized only when they are operated in accordance with actual traffic requirements. Inconvenience, disobedience, and hazard follow unnecessary, arbitrary, or inaccurate operation. The operating standards contained herein provide for a reasonable efficiency in the operation of signals at warranted locations.

It is desirable that a person approaching a traffic signal should presume it is functioning unless he is given a conspicuous and specific indication to the contrary. Hence it is required that all signals in use be "live." When not operating as a Stop-and-Go device, the signal should be operated as a flashing device in accordance with recommendations in sections 208-210 and 279.

During seasonal shutdowns, when it is not desirable to operate the signals, they should be hooded, turned, or taken down so persons will be under no misapprehension that a lamp may be burned out.

Section 189.—Length of Cycle

Considerable dissatisfaction with traffic signals may be attributed to improper timing and selection of cycle length. It is important, therefore, that the predetermined and constant cycle length for fixed-time signals be accurately related to traffic requirements. The cycles of traffic-actuated signals, on the other hand, vary and tend to adjust themselves to the demands of traffic. In this case, the total cycle length is partly or wholly dependent on adjustment of those time controls or cycle components that regulate the reaction of the signal-timing mechanism to vehicle or pedestrian actuations. Obviously, the correct adjustment of these time controls ranks in importance with the selection of a proper cycle length for fixed-time signals.

The cycle shall be as short as will accommodate the necessary movements.

Short cycles encourage observance of the signals by pedestrians and vehicle drivers. Unfortunately, no entirely satisfactory formulae are as yet available for an exact determination of proper cycle length.

For city conditions, a cycle length of from 35 to 50 seconds is generally satisfactory for the usual intersection. Rural intersections, heavy traffic volumes, or complex control problems may make it desirable to use somewhat longer cycles.

Changes in cycle length for different traffic conditions during the day, while requiring special equipment, are oftentimes justified.

Section 190.—Number of Traffic Phases

The number of traffic phases or group movements of vehicles and pedestrians required to obtain proper and efficient operation at an intersection varies with the composition and direction of the traffic flows as well as with the number of entering streets and the general intersection lay-out. A two-phase cycle in which the right-of-way is successively assigned to all movements on one street and then to all movements on the other will suffice for the majority of intersections involving two streets. Intersections having a large and concentrated volume of left turns or unusually heavy pedestrian movements, and those with more than four entering traffic streams, however, will frequently require a division of the total time cycle into three or more phases or grouped traffic movements in order to eliminate major conflicts between vehicles or between vehicles and pedestrians.

The traffic information collected should be most carefully studied for all intersections where the above-named conditions exist, with a view toward keeping the number of phases to a minimum consistent with needs. In determining whether a given intersection should be operated on two-, three-, four-, or multi-phase control, it should be kept in mind that certain unavoidable delays are added as each additional phase is introduced. Where one street carries a low volume of traffic and it is evident from the physical lay-out and the traffic pattern that more than two phases are needed, it is often possible to assign one Go or movement period to the low volume street while the other streets are given two such Go periods.

Section 191.—Rotation of Intervals

Each interval provided for traffic movement should generally be given once and only once during each cycle, but extraordinary conditions may warrant the duplication of an interval in any one cycle. With certain types of traffic-actuated control equipment, it is possible to omit from the cycle those traffic movements for which no demand has been registered. It should be understood that the movement of one particular line of traffic may continue during several intervals. No special indication or interval should be used in a signal cycle until its need has been definitely established by traffic counts and observation.

Following are typical illustrations of the sequence of intervals in simple cycles:

Simple Cycle Without Pedestrian Interval

Interval number	Main street	Cross street
1-----	Green-----	Red
2-----	Yellow-----	Red
3-----	Red-----	Green
4-----	Red-----	Yellow
and repeat.		

Simple Cycle With Combination Pedestrian Interval

Interval number	Main street		Cross street	
	Vehicles	Pedestrians	Vehicles	Pedestrians
1-----	Green-----	WALK-----	Red-----	WAIT
2-----	Green-----	WAIT-----	Red-----	WAIT
3-----	Yellow-----	WAIT-----	Red-----	WAIT
4-----	Red-----	WAIT-----	Green-----	WALK
5-----	Red-----	WAIT-----	Green-----	WAIT
6-----	Red-----	WAIT-----	Yellow-----	WAIT

and repeat.

Section 192.—Traffic Movement Intervals Proportioned to Traffic Requirements

Cycles should be divided into intervals proportionate to the time required by the traffic which will enter the intersection during the signal intervals. Where time requirements of the different movements vary widely during different hours of the day, provision should be made for changing the percentage of the total cycle allowed for each interval to accord reasonably well with these requirements. Where the time requirements of the different traffic movements do not vary materially during the day, the percentages allowed the different intervals should normally be those that most accurately accord with the requirements during the heaviest traffic hour.

Traffic moves in lanes, and the more lanes in use, the shorter is the time required for a given volume to pass through an intersection, assuming that the intersection has adequate discharge capacity. Intervals should not, therefore, be proportioned purely on the basis of relative volumes entering in the different directions unless there is the same number of moving lanes on each entering street. Even then, streets carrying considerable proportions of slow-moving vehicles, or streetcars and busses which must load and unload at intersections, will require more time to discharge a given volume than streets where the traffic is made up largely of passenger automobiles. Adjustment for such differences will often be necessary.

Traffic frequently distributes itself among the available lanes so that each lane requires approximately the same time to discharge its load. Under certain conditions, however, this may not be true. A given lane, because of turning movements, the presence of commercial vehicles, or other factors, may require a greater amount of time than others. This then becomes the critical lane and should be the one considered in proportioning intervals. Usually the volume of traffic per lane entering the intersection on a Go interval will not be equal from the two directions on the same street. The per-lane volume of traffic entering from the heavier direction, therefore, should generally determine the time required for the interval.

Section 193.—Unexpected Conflicts During Go Interval

No movement which may involve an unexpected crossing of pathways of moving traffic should be permitted during any Go interval, except under unusual conditions, when:

1. The movement involves only slight hazard;
2. Serious traffic delays are materially reduced by permitting the conflicting movement; and
3. Traffic subjected to the unexpected conflict is effectively warned thereof.

When such conditions of possible unexpected conflict exist, warning may be given by an illuminated sign or, under certain conditions, by the use of a flashing signal instead of a green Go signal. The foregoing applies to vehicle-pedestrian conflicts as well as to vehicle-vehicle conflicts.

Section 194.—Vehicle-Clearance Interval

A yellow vehicle-clearance interval shall be used following each green interval. In no case shall a yellow interval be displayed in conjunction with the change from red to green.

In general, the vehicle-clearance interval should be not less than 3 seconds, nor more than is reasonably necessary to clear the intersection of traffic. At intersections where approach speeds are 35 miles per hour or more the clearance interval on the street or streets having this approach speed should usually be at least 5 seconds.

While clearance intervals longer than 5 seconds may occasionally be necessary at very wide intersections or under other unusual conditions, they are apt to cause impatience among drivers awaiting the signal change and consequent starting before the green indication appears.

Theoretically, the display of yellow after red has the effect of advising the waiting motorist to prepare to start. In practice, it has frequently induced waiting drivers to start forward in advance of the green indication.

The use of the yellow clearance interval as a period during which pedestrians are supposed to walk is disapproved. The functions of the yellow interval should be exclusively those of warning approaching drivers and clearing the intersection.

Some authorities feel that a short all-way red interval of about 3 seconds' duration immediately after the normal yellow clearance interval has merit at some intersections in that it provides a brief additional clearance period which permits the slower moving pedestrian to complete his crossing without vehicle interference.

Section 195.—Adequacy of Maintenance

Much of the authority and respect that traffic signals have may be traced to their clear-cut compelling indications. Signals with impaired efficiency cannot be expected to command the necessary degree of respect. Proper maintenance is, therefore, of primary importance from this functional viewpoint, and will pay other dividends in increasing the effective life of the signal equipment.

Maintenance should be an important consideration in the design and purchase of traffic signal equipment. If low first cost is followed by high maintenance costs or by serious losses of efficiency, it is obviously poor economy.

The standards set forth herein are intended to provide the essential features for an adequate maintenance program.

Section 196.—Signal Lamp Replacement

Burned-out signal lamps convert traffic signals to the role of a traffic hazard. Immediate replacement of such lamps, or scheduled replacement of lamps short of their anticipated life, is an extremely important maintenance function.

Remoteness of signals from maintenance facilities entails delay in replacement of burned-out lamps. In maintenance jurisdictions where

this condition exists, a regular lamp replacement schedule is advised. Such a schedule should provide for replacements slightly short of the life expectancy as determined from consideration of the following factors:

1. Theory of probabilities of lamp failure as applied to mass production and manufacturers' rating.
2. The effect of differences between socket and rated voltage.
3. Failure due to vibration and handling.

Actual hours of illumination for lamps vary according to lens position and timing schedules. For example, main-street green and side-street red will require replacement more often than side-street green and main-street red. These latter in turn will require replacement more often than the yellow.

Section 197.—Cleaning

The reduction in brilliancy of a signal indication resulting from even a moderate amount of dust and dirt is generally very much underestimated. Signal lenses, reflectors, and lamps should be thoroughly cleaned at least once every 6 months. Lenses and reflectors should always be cleaned when lamps are replaced, unless the last regular cleaning has been very recent.

The frequency with which cleaning is required will vary according to the location of the signal. A signal located on a bridge over railroad tracks may require cleaning once a month.

Section 198.—Maintenance of Controllers

Every controller shall be kept in effective operation in strict accordance with its predetermined timing schedule.

Lubrication.—Controllers shall be carefully lubricated, in accordance with a lubrication chart furnished by the manufacturer, at least as frequently as is specified by the manufacturer and more frequently if experience proves it necessary.

Different controllers often require lubrication at widely different intervals.

Timing.—A careful check of the correctness of timed operation of the controller shall be made frequently enough to insure its operating in accordance with the planned timing schedule.

The checking as to timing can be done effectively in connection with cleaning, lubrication, or overhauling. The length of each interval should be recorded for at least two complete cycles. These should then be checked against the timing schedule, a copy of which should be posted in the control box housing.

The necessity for checking timing arises from the possibility of mechanical or electrical misadjustments or unauthorized changes in timing.

Section 199.—Painting

Signal heads, brackets, poles, posts, control boxes, housings, and conduits above ground should be repainted at least every 2 years, and as much oftener as may be necessary to prevent corrosion and to maintain the good appearance of the equipment.

The frequency with which repainting is needed will vary with the paint, the condition of the surface to which it is applied, chemicals in the atmosphere, and other conditions.

Section 200.—Maintenance Records

Detailed maintenance records should be kept and analyzed at regular intervals to determine future policies as to equipment purchases and the maintenance program.

Good maintenance records are valuable in a number of ways:

1. Careful analysis will assist in determining whether or not the maintenance program in use is satisfactory.
2. Analysis of costs will aid in deciding upon types of equipment to be purchased and improvements in maintenance methods.
3. Maintenance records will frequently be needed by the courts in connection with accident cases.

Maintenance records should indicate the necessary time required and costs of cleaning, lubrication, retiming, overhauling, lamp replacement, painting, and similar items, for each signal installation and for each specific controller.

C—COMPARISON OF FIXED-TIME AND TRAFFIC-ACTUATED CONTROL

Section 201.—Relative Adaptability to Normal Intersection Requirements

Each of the two principal types of traffic signal control, fixed-time and traffic-actuated, possesses certain advantages not afforded by the other. The choice of equipment should be made only after a review of the relative merits and adaptability of the two types to the particular requirements at the location proposed for signalization. While fixed-time control has had by far the wider application up to the present and will very likely continue as the more popular choice for reasons which will be discussed later, the use of traffic-actuated control for certain situations is increasing. The following discussion is intended to bring out the basic differences in the two types of control, insofar as their operating characteristics and suitability for various traffic requirements are concerned.

With fixed-time control, a consistent and regularly repeated sequence of signal indications is given to traffic. The total cycle length, or time required for one complete sequence of signal indications, is a feature of fixed-time control which can usually be adjusted from a minimum of 30 seconds to a maximum of about 120 seconds. A cycle length is selected, based on the traffic demand, and divided into the intervals necessary for handling that traffic. Signal indications then appear in accordance with the predetermined sequence unless changed to other timing schedules by automatic or manual means.

This regularity of timing is both an advantage and a handicap. It permits maintenance of an established time relation with other signals in the area so that vehicles can move through the signalized intersections with a minimum of delay. It does not, however, recognize the short-time variations in traffic flow. In most cases, this means excess or wasted time when cars on one street are required to wait for a signal change although there is no traffic using the other street. These time losses are small but when they occur frequently may cause considerable delay, inconvenience, and reduction in intersection capacity.

With the traffic-actuated type of control, the cycle length is not predetermined or fixed at any definite value. Similarly, the intervals are usually self-adjusting within certain limits so that they more accurately fit the needs of traffic. The sequence of intervals normally

remains the same, but the time for a complete rotation or sequence of intervals will vary widely. This type of control has a considerable measure of flexibility and some of the time and capacity losses inherent in fixed-time control are automatically avoided. This is especially true at intersections where the traffic load shifts from one street to the other during the period of signal operation. Because of the flexibility characteristics of traffic-actuated control, its principal application has been at locations not interconnected with other signalized intersections for progressive traffic movement.

Many operating variations are possible with traffic-actuated control. Intersections may have semi-traffic-actuated or full traffic-actuated control. In the former case, the right-of-way or green signal is normally given to the major street unless a side-street actuation is received, at which time the right-of-way will be temporarily assigned to the side street. This type of control equipment has its principal application at isolated signal locations where traffic on the cross street or route is light and arrives at irregular intervals but, unless aided by signals, is unable to enter and cross the principal route safely without long waiting periods. With full traffic-actuated control, vehicles on all approaches affect the operation of the signal and the assignment of right-of-way is made substantially in accordance with the demands on the several approaches. Complicated intersections often require this type of control to permit a reasonable degree of operating efficiency to be attained.

Section 202.—Special Merits of Fixed-Time Control

Fixed-time control is, as previously mentioned, the more commonly used of the two types of equipment. This is due largely to (1) the simplicity of the equipment, (2) the fact that it provides positive speed control in a signal system, and (3) at many intersections it does an adequate job in controlling intersection traffic. The fixed-time type of control, if carefully timed, can approach very closely the efficiency of traffic-actuated control at intersections where movements are well balanced by direction and where traffic volumes do not vary widely during the day. The equipment is also more easily serviced and maintained than the more complex circuits of the traffic-actuated controller. The constancy of the cycle length is of obvious advantage when signals are interconnected for obtaining progressive movement and centralized control.

Certain additional flexibilities available in fixed-time control permit the use of a different time cycle, cycle division, or offset to meet more precisely the requirements of traffic during the peak and off-peak hours. This change in timing each day may be regular or on a differing program, depending on the requirements encountered. Such programming of control timing is of considerable value and makes for more efficient handling of intersection and system requirements.

Section 203.—Special Merits of Traffic-Actuated Control

The volume of traffic approaching most intersections is a continuously and often widely fluctuating quantity. Maximum efficiency in signalized intersection control is attained when the signal indications are timed so as to reduce to a minimum the delay to traffic using the intersection.

To approach this condition as closely as possible, control mechan-

isms must be able to regulate the signals in accordance with changing demands of traffic. Means must therefore be provided for detecting the presence and volume of traffic, both vehicular and pedestrian, in the approaches to the intersection; and the controller must be able to apportion right-of-way time with maximum effectiveness.

Traffic-actuated control signals operate upon this demand principle. There are two general types of traffic-actuated control: (1) Semi-traffic-actuated control, in which traffic-actuation devices are installed in only some of the approaches; and (2) full traffic-actuated control, in which such devices are provided in all approaches to the intersection.

Among the special advantages of traffic-actuated control are the following:

1. Delay and inconvenience are not great at traffic-actuated controlled intersections because traffic is passed through the intersection in a manner closely approximating the natural approach pattern. Any reduction of delay operates to increase the capacity of the intersection.
2. Traffic-actuated control is especially effective at multiple intersections, or at intersections with traffic requirements that vary considerably during different times of the day.
3. At problem locations in progressive systems, traffic-actuated equipment will usually handle special conflicting movements more expeditiously than fixed-time equipment, particularly if these special movements vary in time requirements at different hours.
4. The full safety advantages of continuous Stop-and-Go operation during low volume periods are retained with traffic-actuated control, whereas fixed-time signals often are switched to flashing operation under these conditions to avoid excess delay in traffic.
5. Traffic-actuated control may, in some instances, minimize the tendency of traffic to avoid signalized intersections, and thus result in the use of more logical routings.

Section 204.—Other Factors Governing Selection of Type of Control

When the problem of choosing between fixed-time and traffic-actuated control equipment is presented, the factor of cost has often been a decisive one. Mainly because of the need for installing detectors in or adjacent to the roadway and the more complex timing circuit in the controller, traffic-actuated signal installations are considerably more expensive than most fixed-time control installations. Due to the wide range in types of fixed-time and traffic-actuated equipment it is not possible to state comparative costs with any exactness, but the more complex types of fixed-time control are the only ones that approach the cost of the simplest traffic-actuated controls. It is most important, therefore, that a careful study be made of the intersection requirements to determine which type of control will be the more appropriate.

If investigation shows that the physical lay-out of the intersection presents no unusual difficulties, that traffic is of substantial volume and reasonably well balanced by direction on both streets and does not change its time requirements too greatly throughout the day, and that no severe pedestrian or turning-movement problems exist, it is likely that fixed-time or traffic-actuated control would be almost equally satisfactory. If the location is close to another signal with which it may now or at some future time be desired to make interconnection for progressive movement of traffic, the fixed-time installation will probably be preferable. However, in cases where the intersection is quite isolated from other signalized intersections, with no intercon-

tion contemplated, and more than two streets or widely varying traffic loads are involved, a traffic-actuated installation will be likely to result in less delay. If, for some reason, a signal has to be installed at a location where conditions do not appear to warrant signalized control, a traffic-actuated signal should be employed because of the lesser delay normally caused to traffic by this type of control.

As is discussed in section 239 dealing with traffic-actuated control in coordinated systems, such equipment can be employed in interconnected progressive systems by superimposing a background time cycle on the control unit. Under heavy demand, the traffic-actuated signal tends to get into a regular schedule of operation resembling that of a fixed-time signal.

Extreme care should be used in selecting both fixed-time and traffic-actuated equipment so that proper features for present and future operation will either be obtained when the controllers are purchased or can be added at a later date when the need develops.

D—FIXED-TIME SIGNALS

Section 205.—Definition

A fixed-time signal is a traffic control signal by which traffic is alternately commanded to stop and permitted to proceed in accordance with a predetermined time schedule.

Section 206.—Advance Engineering Data Required

The installation of fixed-time signals at intersections should be preceded by a thorough study of traffic, roadway, and accident conditions. Among the facts that should be obtained are the following:

1. Complete vehicle volume counts, including right and left turns and classification by vehicle type. These counts should include the periods in an average day when the signal would appear to be most needed, and in all cases should be at least 8 hours in duration.
2. Pedestrian volume counts on each cross walk during the same periods as the vehicle counts.
3. Speed and classification of vehicles on approaches to the intersection.
4. Details of the physical lay-out, such as roadway width, channelization, grades on approaches, corner sight-distance restrictions, bus-stop locations, parking practice, and location of railroad grade crossings. These data are of most value when assembled on a condition diagram, such as is shown in figure 23.
5. A summary of accidents by type, location, vehicle or pedestrian direction, time, etc. A collision diagram covering a year or more of accident experience should be prepared from this information. A typical collision diagram appears in figure 24.

Section 207.—Warrants for Fixed-Time Signals

With such information as will be provided by the above studies, it is possible to appraise the need for signalization in terms of the warrants given below. If the warrant conditions stated are not satisfied and there still appears to be need for signal control, consideration should be given to the use of traffic-actuated equipment (see secs. 233–268 for a discussion of the application of this type of control).

The warrants presented for fixed-time signals are intended primarily for typical intersections of two two-lane, two-way streets or highways.

In some cases separate values are given for city and rural locations, and in other instances the warrants are qualified for special problems such as those which arise at intersections near railroad grade cross-

ings, schools, industrial plants, stadiums, and similar points of public congregation.

Fixed-time traffic signals shall be installed and operated only where and when one or more of the following warrants, as defined in sections 208 to 213, exist:

1. Minimum vehicular volume.
2. Interruption of continuous traffic.
3. Minimum pedestrian volume.
4. Coordinated movement.
5. Accident hazard.
6. Combinations of 1 through 5—other factors.

Section 208.—Minimum Vehicular Volume

The minimum vehicular volume warrants are intended for application at locations where no special conditions exist and where the amount of intersecting traffic is the outstanding reason for intersection conflicts. As previously stated, the warrant values apply to the intersection of two two-lane, two-way streets or highways. Vehicle volume warrants for intersections of roadways having two or more moving lanes in one direction should be somewhat higher than the values given below. Obviously, more traffic can pass through an intersection in a given time in two or three lanes than in one lane.

The minimum vehicular volume warrants are as follows:

*In urban areas:*⁵

1. Total vehicular volume entering the intersection from all approaches must average at least 750 vehicles per hour for any 8 hours of an average day, and
2. Total vehicular volume entering the intersection from the minor street or streets must average at least 175 vehicles per hour for the same 8 hours.

*In rural areas:*⁵

1. Total vehicular volume entering the intersection from all approaches must average at least 500 vehicles per hour for any 8 hours of an average day, and
2. Total vehicular volume entering the intersection from the minor highway or highways must average at least 125 vehicles per hour for the same 8 hours.

On important rural highways, traffic during the highest 8 hours of the average day will usually amount to one-half to two-thirds of the 24-hour total. This means that a total of 6,000 to 8,000 vehicles entering the intersection on an average day is the approximate equivalent of the minimum vehicular volume warrant stated above for rural areas. Peak traffic on summer holidays and Sundays may frequently be twice as high as these values and for approximately half the days of the year the volumes will exceed the stated average of 6,000 to 8,000 vehicles per day.

Recognition of these relationships is most important if the warrants are to be properly interpreted. A signal installation cannot be considered justified under the minimum vehicular volume warrant unless the volumes are recorded on or adjusted to a day reasonably representative of the average condition under which the signal is to be operated.

On urban streets, traffic during the highest 8 hours of the average day is a somewhat more variable percentage of the 24-hour volume than is found on important rural highways. The range of one-half to two-thirds of the total 24-hour volume will nevertheless include a large proportion of the city traffic patterns for average weekdays, which is the time when signals will be of most use. Applied to the

⁵ See page 104 for distinction between urban and rural areas.

urban area warrant stated above, this means that the minimum total vehicular volume entering city intersections must ordinarily be from 9,000 to 12,000 vehicles on an average day, of which total approximately one-fourth must be side-street traffic, before signal installation on the basis of this particular warrant would be justified.

From studies made at isolated signalized intersections, principally in cities, it appears that the peak hour will often be as much as 50 percent higher than the average of the 8 highest hours during the day. Selection of the 8-hour volume warrant period (not necessarily 8 consecutive hours) is based on the knowledge that heavy traffic flows of shorter duration in effect include only morning and evening rush-hour traffic at many locations, which might be better handled by traffic-actuated equipment or by officer control. It is also obvious that a count of 8 hours provides a more reliable measure of need than do shorter period counts.

Regardless of the general warrant stated above, traffic signals should not, if avoidable, be installed at a street or highway intersection near a railroad grade crossing. Traffic signals too close to railroad grade crossings are likely to be misinterpreted by some drivers as governing the periods when it is safe to cross the railroad tracks. If the grade crossing is also protected by standard train-approach signals, there may be considerable confusion between the two types of signal apparatus so close together.

If, however, the minimum vehicle volume warrant is satisfied at an intersection within 200 feet of a railroad grade crossing and if, without signals, traffic is likely to be retarded and vehicles forced to stop on the tracks, a signal installation may be warranted. This type of installation is regarded as exceptional, and extreme care should be taken in all matters relating to the lay-out, design, and operation to avoid the possibility of forcing vehicular traffic to stop on the crossing. To accomplish this, there should normally be an auxiliary control signal at the railroad crossing to stop traffic approaching the intersection from the railroad side when the intersection signal shows a Stop indication and when trains are approaching and crossing the highway. If standard train-approach signals are employed at the crossing, their operation should be positively coordinated with the intersection signal to prevent any possibility of forcing vehicular traffic to stop on the tracks when a train is approaching.

Similarly, coordination of the crossing and intersection signals may be required for traffic moving away from the intersection so as to avoid undue blocking of traffic movement parallel with the railroad while trains are approaching or are on the crossing.

When for a period of two or more consecutive hours the total vehicular volume entering an intersection having fixed-time signals installed under this warrant falls below 50 percent of the minimum volumes stated above for urban and rural intersections, flashing operation shall be substituted for fixed-time operation for the duration of such periods of reduced volume.

In many of the medium and smaller sized communities, a change to flashing operation will frequently be warranted by 8 or 9 p. m. on an ordinary evening. The impracticability of changing the method of operation many times during the day is recognized and therefore it is recommended that flashing operation be limited to not more than three periods in 24 hours.

Section 209.—Interruption of Continuous Traffic

Vehicles on through streets or highways tend, if uncontrolled, to travel through minor street intersections at speeds that make it difficult and hazardous for vehicles and pedestrians from the side street to cross or enter the principal traffic stream, despite laws that require such vehicles on the highway to yield the right-of-way to cross traffic under certain conditions. Where cross traffic suffers undue delay or hazard because of this condition, a signal installation may correct the condition. If several intersections in the same vicinity are similarly affected, a speed-controlling, progressive signal system may be a suitable remedy. However, if such a system is installed, it is generally undesirable to have signalized intersections more than 1,200 feet apart.

Minimum warrants for interruption of continuous traffic are as follows:

In urban areas:

1. At an intersection on an important street, the vehicle volume along that principal street must average at least 750 vehicles per hour for any 8 hours of an average day; and
2. The combined vehicle and pedestrian volume from the side street or streets must average at least 75 units per hour for the same 8 hours; and
3. The average^o vehicle speed must exceed 20 miles per hour on the principal street approaches to the intersection.

In rural areas:

1. At an intersection on an important highway, the vehicle volume along that principal highway must average at least 500 vehicles per hour for any 8 hours of an average day; and
2. The combined vehicle and pedestrian volume from the side highway or highways must average at least 50 units per hour for the same 8 hours; and
3. The average^o vehicle speed must exceed 35 miles per hour on the principal highway approaches to the intersection.

In addition to the above-described conditions warranting signal installation, there are similar instances where traffic signals can provide a genuine service over a somewhat shorter period of time. Industrial plants, resorts, stadiums, and other places where large volumes of traffic are found on regular and reasonably frequent occasions are examples. For this special purpose, there are presented below a series of additional warrants for the interruption of continuous traffic, any one of which may justify signal installation:

In urban areas:

1. Vehicular volume on the major thoroughfare past an establishment of the type mentioned above exceeds 800 cars per hour at the approximate time of major movement of traffic to and from the establishment, and traffic to or from the establishment roadway during the same period of time meets one of the following warrants:
 - (a) A minimum of 300 cars per hour, or
 - (b) A minimum of 200 pedestrians crossing per hour, or
 - (c) A minimum of 200 cars and 100 pedestrians crossing per hour.
2. Left turns into or from the establishment roadway exceed 30 percent of the 800 cars per hour past the establishment.
3. Four lanes of traffic moving past the establishment exceed an average speed of 40 miles per hour during major movement of traffic.
4. A sharp vertical or horizontal curve or view obstruction exists near the entrance or exit of the establishment, one or a combination of which creates a serious accident hazard.

^o This is the arithmetical average of a representative sample of observed speeds of traffic approaching the intersection when there is no signal, Stop sign, or other control feature affecting the measured speeds. The determination of speeds of vehicles approaching intersections should be made for a relatively short distance (say 88 feet) ending at the Stop line, or a location corresponding thereto.

In rural areas:

Warrants for establishments located in rural areas are 50 percent of the foregoing traffic volumes for major thoroughfare and establishment entrance or exit.

When for a period of two or more consecutive hours the vehicle volume on the principal thoroughfare or the combined vehicle and pedestrian volume from the side street or highway falls below 50 percent of the minimum volume stated above for urban and rural intersections, flashing operation shall be substituted for fixed-time operation for the duration of such periods of reduced volume.

Section 210.—Minimum Pedestrian Volume

Provision for safe and convenient crossing of roadways by pedestrians deserves greater attention than it has heretofore received. Nearly two-thirds of all persons killed in city traffic accidents and nearly half the persons killed in all traffic accidents in rural and urban areas combined are pedestrians. The criteria for installation of fixed-time signals on the basis of pedestrian volume are as follows:

In urban areas:

1. Pedestrian volume crossing the major street must average at least 250 persons per hour for any 8 hours of an average day; and
2. Vehicular traffic entering from the major street must average at least 600 vehicles per hour for the same 8 hours; and
3. The average⁷ vehicle speed must exceed 15 miles per hour on the approaches to the intersection.

In rural areas:

1. Pedestrian volume crossing the major highway must average at least 125 persons per hour for any 8 hours of an average day; and
2. Vehicular traffic entering from the major highway must average at least 300 vehicles per hour for the same 8 hours; and
3. The average⁸ vehicle speed must exceed 30 miles per hour on the approaches to the intersection.

When for two or more consecutive hours the vehicular and pedestrian traffic volume drops to 50 percent or less of the warrant values stated above, the signal shall not be operated as a fixed-time signal.

Traffic control signals may be warranted for pedestrian benefit in certain cases where vehicular volume is somewhat less than the warrant values but where vehicular speeds frequently exceed the warrants stated. Such a condition may create a serious traffic hazard. This case might be covered by the accident-hazard warrant described in section 212. At intersections where a pedestrian and vehicle conflict is the predominating factor in determining the need for signal control, special pedestrian signals may be justified. For a discussion of this subject, see section 270.

Conditions at certain nonintersection locations may be improved by the installation and operation of a traffic control signal for the benefit of pedestrians, especially if large numbers of pedestrians must cross roadways at irregular intervals. Such locations are in the vicinity of schools, large meeting places, and parks. Generally such signals should either be of the pedestrian-actuated type or should be operated manually only during periods when they are needed. This type of application is covered more thoroughly in sections 269 to 276, which deal with special pedestrian signals.

⁷ See footnote 6 defining average speed, page 129.

⁸ Ibid.

Studies of pedestrian and vehicular movements are essential to determine whether pedestrian conditions justify the installation and operation of a traffic control signal. The pedestrian study should determine the number of pedestrians crossing each roadway in each direction separately. Persons going to or from a streetcar loading point across one or more moving traffic lanes should be counted. Pedestrian counts should cover at least those hours when it is believed that pedestrian volume crossing the major street may warrant traffic control operation.

To supplement pedestrian and vehicle counts at a given intersection, it is frequently desirable to make studies at other signalized intersections in the same area to determine the degree of driver and pedestrian observance of the signal indications. This should include a record of the percentage of pedestrians crossing on the red indication, the percentage of drivers going through on the yellow or red indication, and especially those making unauthorized turns on the yellow or red indication. If the observance record is poor, it is likely that the value of a signal otherwise justified under this warrant will not materialize without the introduction of other measures designed to secure improved observance.

Section 211.—Coordinated Movement

A fixed-time signal may be warranted as a part of a coordinated signal system if a majority of the signalized intersections composing the system comply with one or more of the established warrants and if the proposed signal installation is necessary to maintain compact group movement or desired group speed. Coordinated control sometimes necessitates traffic signal installations at intersections where they would not otherwise be warranted, for effective regulation of speed and for maintenance of proper grouping of vehicles. By keeping the vehicles in a coordinated system in compact groups and effectively regulating their speed, less delay and greater convenience and safety are accorded both vehicles and pedestrians entering the coordinated roadway at intervening unsignalized intersections.

In general, additional signals for coordinated movement are not warranted if the distance between signalized intersections is already less than 1,200 feet. If there is a choice between intersections to be protected by signals to be installed under this warrant, there should be a careful analysis to determine which intersection most nearly justifies the signal installation under other warrants.

Since signal installations at intersections within 200 feet of a railroad grade crossing are to be avoided, it may be preferable to space signals in a coordinated system somewhat more than 1,200 feet apart in the vicinity of grade crossings. If a signal is needed near the crossing to maintain progression, extreme care should be used in selecting its location, design, and plan of operation so as to preclude the possibility of forcing vehicles to stop on the tracks under heavy traffic conditions.

In designing coordinated signal systems, the question of desirability of installing "spacing signals" to maintain vehicle groupings will frequently arise. In studying the situation, vehicular volume counts as heretofore described should be made at all intersections where the data may be needed. These should be supplemented by observations of speeds of vehicles and the amounts and kinds of delay encountered in moving along the highway.

Section 212.—Accident Hazard

If none of the warrants except the accident-hazard warrant described below is fulfilled, the initial presumption should be against signalization. The installation of a traffic control signal because of a spectacular or much-publicized accident, or because of a small number of accidents, is strongly condemned. The full accident record of the location should be carefully investigated before any installations are made under this warrant. Such study and experience may show at once that the hazard existing cannot be corrected by a device less restrictive than a signal. In general, however, a fixed-time signal may be considered warranted only where:

1. Adequate trial of less restrictive remedies with satisfactory observance and enforcement has failed to reduce the accident frequency; and
2. Five or more reported accidents of types susceptible of correction by a traffic control signal have occurred within a 12-month period, each accident involving personal injury or property damage to an apparent extent of \$25 or more; and
3. There exists a volume of vehicular and pedestrian traffic not less than 50 percent of the requirements specified in the minimum vehicular volume warrant, the interruption of continuous traffic warrant, or the minimum pedestrian volume warrant.

Any fixed-time signal installed because of accident hazard should be operated on the shortest cycle length that will adequately serve traffic approaching during the heaviest traffic hour.

Thorough analysis of accident experience in advance of making installation under this warrant is important. Accident history can usually be obtained from police accident records or from accident reports made by vehicle operators involved. Without a careful analysis of such records it is impossible to determine upon the most suitable remedial measures.

The following four steps are very helpful in determining what should be done:

1. Analyze summarized statistics of all recorded accidents at the intersection.
2. Analyze physical characteristics at and near the intersection.
3. Analyze traffic flow characteristics.
4. Analyze the collision diagram.

A review of these data will frequently reveal a number of significant facts. For example, types of accidents have a very important bearing on the appropriateness of signalization. A traffic control signal, when obeyed by drivers and pedestrians, can be expected to eliminate or reduce materially the number and seriousness of the following types of accidents:

1. Those involving substantially right-angle collisions or conflicts, as occur between vehicles on intersecting streets.
2. Those involving conflicts between straight-moving vehicles and crossing pedestrians.
3. Those between straight-moving and left-turning vehicles approaching from opposite directions, particularly if an independent time interval is allowed during the signal cycle for the left-turn movement.
4. Those involving excessive speed, in cases where signal coordination will restrict speed to a reasonable rate.

On the other hand, traffic control signals cannot be expected to reduce the following types of accidents:

1. Rear-end collisions, which often increase after signalization.
2. Collisions between vehicles proceeding in the same or opposite directions, one of which makes a turn across the path of the other, particularly if no independent signal interval is provided for these turn movements.

3. Accidents involving pedestrians and turning vehicles, when both move on the same Go interval.

4. Other types of pedestrian accidents, if pedestrians do not obey the signals.

As an alternate to installing traffic signals arbitrarily at intersection locations that appear to be hazardous, it is desirable to institute, with proper education and enforcement, remedial measures which cause less delay and inconvenience to traffic. Warning, Advisory Speed, and Stop signs; marking of lanes or otherwise organizing traffic movements; pedestrian and traffic islands; fixed street or highway lighting; removal of view obstructions; and proper regulation of parking are examples. If studies indicate that one or a combination of these other remedial measures is adapted to conditions, it should be given a fair trial for at least 6 months, and preferably for a year. Following the trial period, a restudy should be made, and if satisfactory results have not been achieved, such additional steps should be taken as are indicated by the study.

Section 213.—Combination of Warrants—Other Factors

Fixed-time signals may occasionally be justified where no one warrant is satisfied but two or more are satisfied to the extent of 80 percent or more of the stated values, particularly if there are present other important factors, such as:

1. A sudden change from rural conditions, where relatively high speeds are safe, to those of an urban business district;
2. Extreme width of roadway which pedestrians must cross;
3. Predominance of especially handicapped pedestrians, such as small children or blind, aged, or crippled adults, who need to cross the roadway; or
4. An intersection on or at the bottom of a long or steep grade.

In case 4, there should generally be a traffic control signal at the top of the grade, coordinated with the signal or signals below so that a vehicle permitted to enter the descending grade will be able to proceed at the indicated speed without stopping on or at the foot of the grade. This plan greatly reduces the hazard from vehicles unable to stop on slippery hills.

These exceptional cases should be decided on the basis of a thorough analysis of facts—never on the basis of petitions or complaints alone.

A combination of the above warrants may be used to develop a formula satisfactory not only for determining the feasibility of installing signals at one location but also for arriving at a priority so that a proper sequence for the installation of a number of signals may be determined. Such a formula is also helpful in identifying locations where traffic signal operation is no longer necessary.

Section 214.—Selection of Type of Fixed-Time Control Mechanism

Where any of the previously described warrants is satisfied and the decision has been made to install a fixed-time signal, it is necessary to select the type of fixed-time control mechanism⁹ to be used. The possible choices include the following, the advantages and limitations of which are set forth in sections 215 to 218:

1. Nonsynchronous fixed-time controller for isolated intersections.
2. Program type of fixed-time controller for isolated intersections.
3. Synchronous type of fixed-time controller for isolated intersections.
4. Controllers providing for coordination.

⁹ *Pre-Timed, Fixed Cycle Traffic Signal Controllers*, Technical Report No. 2, Institute of Traffic Engineers.

Section 215.—Nonsynchronous Fixed-Time Controller for Isolated Intersections

This type of controller is the least desirable. Its operation, and hence the resultant timing, varies with changes in line voltage and temperature. Controllers of this type already purchased should be shifted to relatively unimportant isolated intersections warranting signalization where:

1. There is little likelihood that the signal installation will ever be coordinated with any other; and
2. The fixed lengths of cycle and intervals will be tolerable during all hours of traffic control (Stop-and-Go) operation.

Section 216.—Program Type of Fixed-Time Controller for Isolated Intersections

This type of controller provides for a limited number of changes in cycle length and in the proportions allotted to various Go intervals. Such controllers may be used at isolated intersections where:

1. There is little likelihood that the signal installation will be coordinated with any other;
2. There are marked variations for considerable periods in the traffic demand, as, for example, where the major traffic stream enters on different Go intervals in the morning and evening peak periods; and
3. With this program in effect, delays are not unreasonable.

Section 217.—Synchronous Type of Fixed-Time Controller for Isolated Intersections

This type of controller involves the use of a synchronous motor and should be used at isolated intersections where:

1. The installation is likely to be coordinated with one or more other signal installations but interconnection with a master controller is determined to be unjustified economically; and
2. The fixed length of cycle and intervals will be tolerable during all hours of traffic control operation.

This type of controller is almost always preferable at intersections for which the nonsynchronous type is suitable.

Section 218.—Controllers Providing for Coordination

Two types of control are available for coordination. One of these involves noninterconnected synchronous motors, the other a master controller interconnected to local controllers at each signal installation in the system. Sections 225 and 226 discuss the various degrees of flexibility attainable by these two types. The selection should be based upon:

1. The volumes of traffic involved;
2. Variations in traffic volume during the hours of intended Stop-and-Go control;
3. Variations between traffic volumes in the two directions on the highways involved; and
4. An analysis of the differences of cost involved.

In general, the noninterconnected synchronous motor plan should not be used for very heavy traffic because of its limitations as to flexibility and because of the absence of assurance that the desired coordination will continue indefinitely. If funds do not immediately permit interconnection and the use of a master controller, it is possible to install synchronous motor controllers of a type which can later be utilized in a very flexible type of system. Under such conditions, the use of synchronous controllers of this type is recommended.

Section 219.—Signal Timing in Accordance With Traffic Requirements

As pointed out in the discussion of signal operations in sections 188 to 194, the full value of a signal installation is realized only when it is operated in a manner consistent with the traffic requirements. The use of unduly long cycles, or improper division of cycles of reasonable length, fosters disrespect and poor observance of signal indications. Signals should not be operated manually more than is absolutely necessary, as this type of operation has frequently proved to be more inefficient than properly timed automatic control. This is particularly true of signals in a coordinated system.

One of the principal difficulties in signal timing comes from the need to accommodate two or three radically different volume patterns at various times during the period of operation. Any timing plan which is devised should be checked against the traffic-count information collected to be sure that the inevitable volume changes on the streets concerned will be handled in the best possible manner.

This problem can become exceedingly complex when it involves not one but a series of signalized intersections which are to be operated so as to provide for continuous movement of a platoon of vehicles. Varying block lengths often constitute a major difficulty in arriving at a satisfactory timing plan. There are many details involved in the development of efficient time-space diagrams for progressive signal systems and no attempt will be made to present a full treatment of the subject in this manual. The *Traffic Engineering Handbook*, published by the Institute of Traffic Engineers and the National Conservation Bureau, contains a helpful discussion of the significant details of signal timing and describes a number of practical refinements possible in traffic signal systems.

Section 220.—Division of Total Cycle Time

Reference has been made to the importance of assigning Go time to the intersecting streets in accordance with the traffic demand. There follows a description of a method that has been employed successfully:

If, during the heaviest traffic hour, the effect of turning movements, slow-moving commercial vehicles, and other factors on the time spacing between vehicles in the critical lane leaving the intersection is equal for the two heavier traffic flows at right angles, the division of the total time cycle into the two Go periods will be approximately correct if these periods are made directly proportional to the intersecting volumes of traffic per critical lane.

However, if, during the heaviest traffic hour, there is a considerable difference in the time spacing between vehicles in the two intersecting critical lanes because of, say, the presence of trucks and busses in one of the critical lanes and not in the other, this fact should be taken into account. In making the cycle division, the Go periods will be approximately correct if made proportional to the products of the critical lane volumes and the time spacings on the respective intersecting streets.

To illustrate, assume that a 60-second cycle has been selected and that the time required for vehicles to clear the intersection after the green signal is 5 seconds on each street. This leaves a total of 50 seconds of Go time to be divided between the two streets. Assume that the critical lane volumes V_A and V_B on streets A and B during the heaviest traffic hour are 400 and 250 vehicles, respectively. In the first case, assume that the time spacing between vehicles, or headway on departure, for each of the two streets is the same. The Go time assigned to each street, T_A and T_B , would then be approximated as follows:

$$\frac{T_A}{T_B} = \frac{V_A}{V_B} = \frac{400}{250} \text{-----} (1)$$

and $T_A + T_B = 50$ seconds (total Go time) ----- (2)

Solving for T_B in (2) and substituting in (1) :

$$\frac{T_A}{50 - T_A} = \frac{400}{250}, \text{ whence } T_A = 31 \text{ seconds.}$$

From (2), $T_B = 50 - 31 = 19$ seconds.

In the second case, assume that the time spacing between vehicles, or departure headway, H_A and H_B , is 3 seconds on street A and 5 seconds on street B. This difference in headway might be caused by a sizable percentage of trucks in the critical lane on street B. The division of the Go time would then be approximated as follows :

$$\frac{T_A}{T_B} = \frac{V_A \times H_A}{V_B \times H_B} = \frac{400 \times 3}{250 \times 5} \text{ ----- (3)}$$

Solving for T_B in (2), and substituting in (3) :

$$\frac{T_A}{50 - T_A} = \frac{400 \times 3}{250 \times 5}, \text{ whence } T_A = 24 \text{ seconds.}$$

From (2), $T_B = 50 - 24 = 26$ seconds.

It should be emphasized that such calculations provide only an approximate means of determining the proper time for each street. Other considerations, such as the time required for pedestrian crossings and physical conditions at the intersection, also affect signal timing. After the initial selection of a cycle length and a timing program, frequent checkbacks and studies of the signal in operation should be made to obtain the most efficient timing schedule.

As a general principle of traffic signal timing, no vehicle Go interval should be less than the time required for the waiting group of pedestrians to get started and to cross to a point of safety unless an exclusive pedestrian interval is also employed. Experiments with signal timing have shown that, insofar as vehicle movements are concerned, excellent efficiency can be attained under certain off-peak conditions with Go intervals as short as 15 seconds. Ordinarily, however, they must be somewhat longer to give the pedestrian a safe opportunity for crossing the roadway.

When the pedestrian crossing time runs concurrently with the vehicle Go period, which is the usual case, the total Go interval should be long enough to allow not less than 5 seconds during which it is indicated that pedestrians may start to cross, and enough longer to permit pedestrians who have entered the roadway to reach a place of safety with the additional time provided by the vehicular clearance interval. Thus if it takes 14 seconds for most pedestrians to cross the roadway or reach a point of safety, and if the vehicle clearance (yellow) interval is 3 seconds, the total Go (green) interval should be at least $5 + 14 - 3$, or 16 seconds.

Section 221.—Coordination of Fixed-Time Signals

In general, all fixed-time signals within 1,200 feet of one another and controlling the same traffic should be operated in coordination. Even at greater distances coordination may be desirable under certain conditions (see sec. 231 for required coordination with railroad grade-crossing signals).

Great inconvenience and delay result from independent, noninter-related operation of closely adjacent signal installations operating on fixed-time control. Most of this delay can be eliminated by carefully planned coordination. However, under certain adverse conditions which seriously affect the efficiency of coordinated control, greater efficiency may be possible with traffic-actuated control, operated either

independently or in combination with coordinated control (see sec. 239).

Section 222.—Types and Selection of Coordination

The most useful classification of traffic control signal systems is based on their method of coordination. Since the primary purpose of this coordination is to organize and facilitate traffic flow, it is essential to understand what vehicular traffic will do under the various systems. On this basis of classification there are four general types of coordination of fixed-time signals. These are defined as simultaneous system, alternate system, progressive system, and flexible progressive system.

Section 223.—Simultaneous System

In a simultaneous system all signals show the same indication to the same highway at the same time. This is one of the early types of signal systems and it has a very limited application in modern traffic signal practice.

In its simplest form it involves the use of one controller for a series of signals. At all intersections the timing is precisely the same and indications change simultaneously to show green at each signal facing main street traffic and red to all side streets, and similarly throughout the cycle. A basically simultaneous system may be made more efficient by utilizing independent controllers at critical intersections to permit some adjustment in interval timing in accordance with local intersection requirements.

Intersections less than 300 feet apart often constitute a serious coordination problem. At normal traffic speeds the time required to move from one intersection to the next is so short that a very short cycle would be required for a flexible progressive or alternate system of control. If only two such intersections are to be coordinated, the best plan is generally to operate them as a simultaneous system, giving an ample Go interval on the main street for a major portion of the traffic to clear through both intersections. If two such close intersections are encountered in a larger group to be coordinated, the best plan is to select the flexible progressive system and to adjust the offsets at the two closely adjacent intersections so as to interfere the least with the continuous movement of traffic. Frequently this will result in virtually simultaneous operation of these two signal installations. Except for this limited application and perhaps other occasional exceptions, the use of the simultaneous system is not recommended.

In most applications the simultaneous system has serious operating disadvantages:

1. The simultaneous stopping of all traffic along the highway prevents continuous movement of vehicles and tends to result in high speed between stops, but low over-all speed.
2. Cycle length and interval proportioning are usually controlled by the requirements of one or two major intersections in the system. This often creates serious inefficiencies at the remaining intersections.
3. On streets carrying numerous streetcars, there is an extremely heavy power drain at the beginning of the Go interval.
4. When the main street is completely filled with a continuous line of traffic and this traffic is stopped on a red indication, vehicles from the side street often have difficulty in turning onto or in crossing the main street.

Section 224.—Alternate System

In the alternate system all signals change their indications at the same time, but adjacent signals or groups of signals show opposite

indications alternately along a given highway. The alternate system is usually an improvement over the simultaneous system in that throughout a series of intersections so controlled there can be, under favorable conditions, continuous movement of groups of vehicles at a predetermined speed, this being completely achieved only where the lengths of the blocks, or of the alternating groups of blocks, are equal. The inflexibility of the alternate system lies in the fact that the main street cannot at any intersection have more than half the cycle for a Go interval without a corresponding loss of time for the Go interval at an adjacent intersection. Hence, for maximum efficiency of through movement the cycle must be divided into equal Go and Stop intervals. Under this condition the side streets all receive as much Go time as the main street, which is ordinarily not consistent with the relative requirements of traffic on the main and side streets.

The alternate system can be operated with a single controller, but this arrangement is not recommended. Although the alternate system can be used on a street where blocks are of equal length to control speeding and to provide equal facility of movement in either direction through the system, it does have limited application for the following reasons:

1. It requires substantially equal Go intervals for both main- and side-street traffic, which is likely to be inefficient at most of the intersections.
2. It is not well adapted to a street having blocks of unequal length.
3. If the signals are alternated by groups the capacity of the roadway is materially reduced during heavy traffic since the latter part of the vehicle group will be stopped by the second signal in the group (assuming they are being operated in pairs) when the signal indication changes.
4. Adjustments for changing traffic conditions are difficult to make.

Section 225.—Simple Progressive System

In the simple progressive system, a common cycle length is used at each intersection and Go indications are given independently in accordance with a timing schedule designed to permit continuous or nearly continuous movement of groups of vehicles along the highway at a planned rate of speed.

Synchronous-motor-driven controllers operated by a common or electrically synchronized source may be employed without interconnection in the progressive system and this will serve satisfactorily until some difficulty causes one or more of the controllers to get out of step. The proper time relation between signal indications at the various locations in the system must then be re-established by adjusting, with the aid of a stop watch, the offsets of those timers which are out of step.

If a master controller is used and connected to a circuit which runs to all signal controllers in the system, there can be a constant supervision of the time relation between successive signal indications, and timers can be required to keep in step. Flashing signal operation can be obtained at any or all intersections, either by local time switch if non-interconnected or from the master controller if interconnected.

The simple progressive system is normally far more efficient than either the simultaneous or the alternate system but does not provide the full flexibility possible in a completely modern traffic signal system.

Section 226.—Flexible Progressive System

The flexible progressive system incorporates all the advantages of the simple progressive system and has a number of additional ad-

vantages. A common cycle length is used throughout, but Go intervals are scheduled independently to meet to the extent possible the demands of traffic for movement through the system as well as at individual intersections. Through the use of modern two- and three-dial equipment, timing adjustments to meet efficiently the widely varying needs of traffic at individual intersections and throughout the system are possible. Predetermined timing programs can be set up on the multi-dial controllers to favor rush-hour movements at appropriate periods during the day or week, midday or off-peak traffic demands, and other conditions requiring special timing schedules and coordination. Such refinements offer great advantages over the unchanging timing plans of earlier progressive signal systems. Careful measure of the demands of traffic and of the potential value of the flexibility features in the multi-dial systems should be made before acquiring control equipment for use in flexible progressive systems.

True flexibility is obtained by the interconnection of all controllers in the system with a master controller to permit not only the supervisory check of the coordination between signals but one or more of the following additional features:

1. Remote control of changes in offset relation between controllers to favor movement in one direction at certain times, such as for inbound and outbound peaks.
2. Remote control of changes in total time cycle or in interval timing, or both, to meet the varying requirements of traffic at various periods of the day.
3. Flashing signal operation at any or all intersections.

In general, a properly designed and operated flexible progressive system is the fixed-time system best adapted to the efficient movement of traffic. Its advantages include the following:

1. Continuous movement of entire groups of vehicles is possible with a minimum of delay and at an average speed planned for the system. This advantage can be realized on both the main and side streets.
2. A high degree of efficiency can be obtained by proportioning the intervals to fit the traffic requirements at each intersection.
3. Speeding is discouraged because a vehicle must make frequent stops if it exceeds the speed for which the system is planned.
4. Differences in block lengths can be handled better than with other fixed-time systems.

Section 227.—Conditions Affecting Efficiency of Signal Systems

Certain conditions seriously reduce the efficiency of signal systems, even of the best flexible progressive systems. Among these are:

1. Very short street blocks (assuming signals at all intersections) especially where reasonably high speeds are possible (this particular condition does not affect the simultaneous system).
2. Narrow streets, where parking and loading interfere with free movement.
3. Traffic composed of units of widely differing speeds, such as streetcars, busses, trucks, and passenger automobiles, especially on narrow streets.
4. Certain types of complicated intersections, such as those requiring three or more Go intervals per cycle.
5. Heavy volumes of vehicles turning from or into the artery, especially if the block into which they turn is short or otherwise limited in capacity.

Nevertheless, some type of flexible progressive system generally gives the best results possible by fixed-time control under such street and traffic handicaps as cannot be removed or relieved.

When conditions along a given highway where it is desired to install a signal system are not particularly favorable to fixed-time flex-

ible progressive control, consideration should be given to the possibilities offered by progressive traffic-actuated control or independent traffic-actuated control (see sec. 239).

Section 228.—Manual Control

At heavily traveled intersections operating under isolated control, manual operation of signals at certain times may be warranted by varying traffic requirements. The provision of apparatus to permit manual operation of signal installations in a flexible progressive system, however, is not generally recommended.

Experience has shown that if manual control features are available a tendency on the part of the police to operate certain intersections manually is apt to develop. This often destroys coordination at those intersections and through the system, with disadvantages generally more important than the possible improvement achieved by proportioning intervals manually. The presumption should be strongly against manual control in coordinated systems until the inability of automatic control to meet the situation at the particular intersection is proved.

Section 229.—Speeds for Progressive Systems

The speed or speeds for which a flexible progressive system is designed should accord reasonably with what speed studies show would be the speed of vehicle movement if cross-traffic delays were eliminated. After drivers have become accustomed to a progressive system, it may be possible to increase the speed with safety.

High speeds should be avoided, especially in busy urban districts. Except in business districts, progressive systems along arteries are generally timed for speeds ranging from 20 to 30 miles per hour. In general, the more heavily used the artery, the narrower the roadway, the more built-up and busy the district, the shorter the blocks controlled, the more mixed the types of traffic, or the more pedestrians and cross-street traffic there are, the slower should be the design speeds.

Local authorities should be careful to avoid design speeds that will conflict with State laws governing speeds.

Section 230.—Signs Indicating Timed Speed

Traffic Signal Speed signs (sec. 38) should be erected to guide drivers operating under an alternate, simple progressive, or flexible progressive system. Where the system timing is different for various periods of the day, however, the resulting speeds may vary enough to make this posting of speed signs impractical. When such signs are used, they should be mounted on, or as near as possible to, each signal where the timed speed changes, and at intervals of not more than two blocks throughout the system.

Section 231.—Coordination With Railroad Crossing Signals

Traffic signals near railroad crossings shall be interconnected with the flashing light or wigwag signals or gates at the railroad grade crossing and with all other traffic signals on the same street or intersecting street within 500 to 1,000 feet of the crossing, to the extent necessary to prevent conflicts between rail and highway traffic. The signals shall be so operated as to prohibit, to the maximum extent practicable, vehicles from entering the roadway between the railroad crossing and the intersection near

the crossing as trains approach and travel through the crossing area.

On the approach of a train, all signals which could permit vehicles to reach the crossing area without having another red indication before them shall, unless already showing red, go immediately to yellow and then to red, remaining red until the crossing is clear. At all other times, these signals should operate as standard flashing signals or as Stop-and-Go signals, depending on the conditions warranting their installation.

Section 232.—Rate of Flashing

When fixed-time signals are put on flashing operation, the rate of flashing shall be not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be approximately equal to the nonilluminated period.

Detailed information on flashing signals will be found in sections 278–283. In every case, the change to flashing operation should be made during or immediately following the main-street green interval.

E—TRAFFIC-ACTUATED SIGNALS

Section 233.—Definition

A traffic-actuated signal is a type of traffic control signal in which the intervals are varied in accordance with the demands of traffic as registered by the actuation of detectors or push buttons.

1. A semi-traffic-actuated signal is a type of signal in which means are provided for traffic actuation on only some of the approaches to the intersection.

2. A full traffic-actuated signal is a type of signal in which means are provided for traffic actuation on all approaches to the intersection.

3. A speed control signal is a type of signal in which means are provided for traffic actuation on some or all approaches and which provides Go indications in such a manner that vehicle speeds on one street are limited to a preselected maximum value.

Section 234.—Warrants for Intersection Control

Because traffic-actuated signals at intersections do not normally delay traffic except when it needs to be delayed to avoid conflict with traffic on cross streets, it is not advisable to set values of minimum traffic volumes or other fixed warrants for their installation. There are, however, a number of factors that should be considered and weighed before selecting and installing such signals. These factors are:

1. *Vehicular volumes.*—At intersections where the volume of vehicular traffic is not great enough to justify fixed-time signalization, traffic-actuated signals may be applied if other conditions are such as to indicate the need for Stop-and-Go signal control and if the cost of the installation can be justified by the conditions.

2. *Cross traffic.*—When the volume of traffic on a main street is so great as to restrict and jeopardize unduly the movement of vehicular cross traffic on a minor street, semi-traffic-actuated signals may be installed to provide assignment of right-of-way to the cross street without seriously delaying traffic on the main street. Traffic-actuated signals are desirable at all such signalized intersections, except in cases when they constitute a part of a coordinated or progressive system, thus warranting fixed-time control.

3. *Peak-hour volumes.*—When signal control is required at an intersection during only a small part of the day, such as during peak traffic hours, traffic-actuated signals may be installed if economically justified, since they will not unduly delay traffic at other times.

4. *Pedestrians.*—If the principal need for a traffic signal is to accommodate pedestrian traffic, traffic-actuated signals are usually desirable and may be economically justified. Most urban intersections with heavy pedestrian volumes also have heavy vehicular volumes and thereby warrant the use of fixed-time signals. However, signals may be warranted at special locations, such as in the vicinity of schools, when pedestrian crossings are the primary consideration. In these special cases, traffic-actuated signals will delay vehicular movements only when the streets are in use by pedestrians.

5. *Accident hazard.*—When a study of intersection conditions indicates that signalized control would be an effective remedy for the accident hazard existing, but the minimum warrants established for installation of fixed-time signals are not met, a traffic-actuated signal installation may be justified.

6. *Wide traffic fluctuations between streets.*—When the preponderance in traffic varies from one street to another, at an intersection where one or more of the warrants for fixed-time signals is substantially fulfilled, full traffic-actuated control will usually provide the greatest efficiency in intersection operation.

7. *Complicated intersections.*—Traffic-actuated signals offer special advantages at complicated intersections with conditions substantially warranting signals, where multiple traffic phases are needed, in that they are capable of skipping phases when some of the streets are not being used. In each case, they use only the time actually then required, thus providing a high degree of efficiency.

8. *Unwarranted signals.*—When traffic authorities are compelled to install traffic signals at locations where they are not needed for safe and efficient movement, traffic-actuated types should be employed. They cause a minimum of unnecessary delay and thus do not tend to break down public respect for traffic signal control.

9. *Progressive signal systems.*—When the spacing or character of some intersections in a fixed-time progressive signal system is such that satisfactory progressive timing cannot be achieved, traffic-actuated control may be employed at those intersections.

10. *Speed control.*—If approach speeds present a particular hazard at intersections, in addition to normal intersection problems, full-actuated control employing speed control on the artery may be installed for best results.

Section 235.—Warrants for Nonintersection Control

Special conditions at roadway locations other than intersections may warrant the installation of traffic-actuated signals. Some of the factors that may justify such installations are:

1. *Speed control.*—Traffic-actuated signals may be used to control speeds at the approaches to special roadway locations, such as bridges, sharp curves, and entrances to towns. They may be of especial value at school zones if speeds average higher than 35 miles per hour in rural or 25 miles per hour in urban areas.

2. *One-way restricted zones.*—At locations on two-way roadways where traffic can only move in one direction at a time, such as at narrow bridges and tunnels, traffic-actuated signals may be applied to assign the right-of-way and to provide clearance intervals in accord with traffic requirements.

3. *Midblock pedestrian protection.*—Pedestrian crossings concentrated at schools where intersections are a considerable distance apart, and at other midblock points, often justify use of pedestrian-actuated signals.

The installation of signals between intersections for the purposes indicated above should be accompanied by the erection of appropriate signs advising the motorist of this special application. Immediately subsequent to installation, there should be a period of strict enforcement so that disrespect for signal indications will not develop.

Section 236.—Types of Traffic-Actuated Control, and Factors Governing Selection

As indicated earlier, traffic-actuated signal controls may be classified in two general categories: (1) Semi-traffic-actuated, and (2) full traffic-actuated. There are also several special types of applications for traffic-actuated equipment. These include: (1) coordinated control, (2) pedestrian-actuated control, (3) speed control, and (4) one-

way restricted zone control. All these special applications make it essential that a thorough knowledge of the traffic and physical facts be obtained prior to selecting equipment for installation.

To aid those who have the problem of choosing the proper type of equipment for a particular job, the characteristics of the two general types of traffic-actuated control and the several special applications are presented below.

Section 237.—Semi-Traffic-Actuated Control

Semi-traffic-actuated control is applicable primarily to intersections of a heavy-volume or high-speed traffic artery with a relatively lightly traveled minor street. Detectors are located only on the minor street. The signal is normally green on the artery, changing to the minor street only as a result of vehicle or pedestrian actuation. In some types of controls the minor street green interval is of fixed duration, but in the more flexible types the duration of the minor street green interval is proportioned to the traffic demand thereon, with provision for a maximum limit beyond which the green light may not be retained on the minor street even when traffic demand thereon is heavy. Upon the expiration of the required, or maximum, minor street interval, the Go signal will revert automatically to the artery where it must remain for at least a predetermined minimum interval. At the expiration of this minimum interval the control is again free to respond at once to minor street actuation.

Section 238.—Full Traffic-Actuated Control

Since semi- or part traffic-actuated control does not measure the demands of certain traffic streams, it cannot attain the efficiency of full traffic actuation. Therefore, full traffic-actuated control should be selected for intersections where failure to take into account certain traffic demands will seriously affect the efficiency of control. In full traffic-actuated control, detectors are installed on all approaches to the intersection and right-of-way is assigned to a street only as a result of actuation thereon. When there is no traffic on either street, the green indication will ordinarily remain upon the street to which it was last assigned. The duration of the green interval on any street is dependent upon the traffic demand on that street, subject to a maximum time limit in the event of a continued demand and the presence of traffic on the other street. In the event of continued actuation, transfer of right-of-way will be made to waiting cross traffic after a predetermined maximum period, and in this case, right-of-way will automatically be returned to the first street at the earliest opportunity without the necessity of further actuation.

Full traffic-actuated control can be applied to more than two-phase operations. Equipment is available for three- and four-phase intersections. Operation of controllers at such intersections is similar in principle to operation at two-phase intersections. Opportunity for the right-of-way is accorded to the several phases in rotation and phases for which there is no traffic demand are skipped. In three- or four-phase controls, provision can be made for allowing additional noninterfering traffic flows to move during more than one phase. Thus, a three-phase control may handle four or five flows, provided only three of them are commonly interfering.

A recently developed form of full traffic-actuated controller operates upon a "volume-density" basis, many of its circuits being subject to

automatic and continuous adjustment with respect to variations in volume, relative densities on the two opposing traffic phases, elapsed time between actuation and assignment of right-of-way, and other factors. As this form of control is essentially "platoon responsive," it is capable of facilitating progressive platoon movements. This is discussed in the following section on coordinated control.

Section 239.—Coordinated Control

There are three principal applications of traffic-actuated equipment in coordinated operation of a series of related signalized intersections. These are characterized by the features described in the following paragraphs:

Supervisory background cycle.—In one type, a supervisory background cycle is imposed upon a series of semi-traffic-actuated controls, this being accomplished by a master timer sending out impulses over interconnecting wires to each semi-actuated controller, or by local synchronous motor control at each intersection.

The background cycle is set up in the same manner as for fixed-time control, a time-space chart being worked out for the series of intersections that will give the maximum travel band through the area. The function of the supervisory cycle is to assure that the local semi-actuated controllers provide at least the minimum of Go time, and in the time relation called for in the time-space chart. In addition to this minimum Go time, each semi-actuated controller adds to its artery Go interval all time not required by traffic-actuated demand on the minor street, thereby providing the widest possible travel band. One possible disadvantage is that such an extended Go interval may seriously overload a subsequent intersection at which cross-traffic requirements are greater.

It is also apparent that the above type of operation does not provide the speed control characteristics of a fixed-time progressive system, and hence should be used only where the consideration of moving maximum amounts of traffic with the least delay outweighs the desirability of speed limitations.

Volume density control.—Another form of coordinated traffic-actuated control is accomplished by the use of full-actuated controllers of the so-called volume-density type. This type of control operates so that no background cycle or interconnection is used. The controller is capable of responding to the natural platoon movement of traffic. The impulses from an advancing platoon of cars are received by the controller and tend to produce a forcing effect in securing a Go interval for the group of vehicles, this tendency being increased by a carry-over effect impressed upon the control mechanism by the passage of the previous platoon. Increased spacing of vehicles at the end of the platoon is sensed by the controller and utilized to terminate the movement. It is thus possible for platoon movements to affect a series of traffic-actuated intersections of this type in such a way as to set up a pattern of progressive movement based on natural speeds and spacings.

Special use in a flexible progressive system.—A further application of traffic actuation in the field of coordinated movement occurs in a fixed-time flexible progressive system where intersection spacing at one or more points in the system may be such that the best possible progressive timing arrangement involves considerable reduction or displacement in the progressive Go band. Multiple intersections in a progressive system may also cause difficulties in the time-space chart. In these instances, full traffic-actuated control may sometimes be effectively employed to bridge the gap.

Section 240.—Pedestrian-Actuated Control

Operation of both the semi- and full traffic-actuated controls, as well as certain types of fixed-time controls, can be accomplished by pedestrian push buttons. Such actuation may affect movements in any of the following ways:

1. Pedestrian actuations are handled on the same basis as vehicle actuations. No special signal indications are shown for pedestrians.

2. Pedestrian indications (WALK, WAIT, or equivalent) are shown in parallel with the vehicle indications. The most desirable types of such controls provide for a termination of the Walk indication sufficiently in advance of the expiration

of the vehicle interval to permit persons who have left the curb to complete the crossing of the street without vehicular interference.

3. An exclusive pedestrian interval, normally justified only under conditions of low vehicle volume at high speeds and heavy pedestrian movement, is inserted in the signal cycle and during this interval all vehicle traffic is stopped.

4. In the case of pedestrian-actuated signals that normally operate in conjunction with fixed-time intersection signals and which have the pedestrian interval introduced into the cycle upon actuation of the push button, the pedestrian interval can either be taken from one of the vehicular traffic green-light periods or be added to the cycle without decreasing either of the green periods. During flashing operation of signals at night (secs. 167, 279), actuation of the push button changes the flashing signals to give a steady red Stop indication to the major traffic flow crossed by pedestrians, with or without a special Walk signal.

Equipment is also available for the protection of pedestrian cross walks at midblock locations, schools, and similar locations. With this form of control the green signal shows normally to traffic on the thoroughfare, right-of-way being accorded to the cross walk upon push-button actuation. After providing an interval for pedestrian movement, these signals automatically return the right-of-way to vehicular traffic, and give a predetermined and adjustable minimum interval to this traffic before the pedestrian indication can again be obtained.

Section 241.—Speed Control

Speed control can be applied at nonintersection locations and also at full traffic-actuated controlled intersections.

Nonintersection speed control.—An adaptation of the traffic-actuation principle affords a means of controlling the speeds of vehicles at nonintersection locations such as curves, bridges, and school zones. The component parts of the system are a speed controller, a vehicle detector, and a traffic signal. The signal indication is normally red or Stop. Detector actuation at a point in advance of the signal initiates the timing of a delay interval after which the signal is changed to a green or Go indication in time to permit the passage of a vehicle traveling at or below the maximum allowable speed (i. e., covering the distance between detector and signal in not less than the timed interval). A vehicle traveling at too great a speed will arrive at the Stop line before the signal changes from Stop to Go and hence will be required to stop. Succeeding vehicles, if closely enough spaced, will extend the Go indication, but when the maximum spacing is exceeded the red indication is at once shown and speed control again becomes effective.

This type of control should always be identified with appropriate signs so that the motorist will recognize and understand the function of the signal. For the same reason, some additional enforcement may also be desirable for a period immediately after the installation is made.

Intersection speed control.—At intersection locations where speeds on the artery approach present a particular hazard in addition to the normal problems of intersection control, it may be desirable to employ full traffic-actuated control incorporating speed-control features on the artery.

All signals normally show red in the absence of approaching traffic. A single vehicle approaching the intersection on the main street and crossing the detector will receive the green indication at the end of a vehicle approach period. If the vehicle is traveling at or below the speed designated as safe for the location, the green indication will

come on in time to allow passage through the intersection without delay. If, on the other hand, the approaching vehicle is coming too fast, it will have to slow down or stop before the green indication will be displayed.

A car following close enough so that it crosses the detector before the green indication period for the first car expires will extend the given period, thus allowing itself time to pass the intersection. A platoon of cars can all proceed through the intersection, by this extension feature, without interruption. The speed control inherent in this latter case lies in the fact that the first car of the platoon is monitored for speed as it approaches the intersection. Should a break occur in the line of cars long enough so that the speed of the next car will not be so controlled the signal will have returned to red. This car upon crossing the detector will institute a new vehicle approach period and thus monitor its own speed.

The vehicles approaching the signal on the main street from one direction and obtaining the green indication do not cause the same indication to be displayed toward the other direction on the main street. Signals facing in the opposite direction on the main street remain red in order to have a speed-monitoring effect on traffic which may approach from that direction.

When the signal is not to transfer the right-of-way to the cross street, the main-street indication changes directly from green to red in order to give immediate speed-monitoring effect for other approaching vehicles. This is a satisfactory procedure inasmuch as had the next following car been close enough to get into trouble it would have been close enough to extend the green light period.

If cross traffic is waiting and traffic is moving through the intersection in one direction on the main street, a driver approaching the signal from the other direction on the main street will not receive a green indication unless there is time for him to go through the intersection before right-of-way is transferred to the cross street. If there is not sufficient time before the right-of-way transfer is made, the green light will be returned to the waiting driver on the main street after the cross-street traffic has passed. On the cross street the display of the red signal is always preceded by a yellow signal as in normal signal operation.

A clearance interval is always provided for the main street when the green signal is to be given to the cross street. If there are cars on the main street between the detector and the intersection that must be stopped a yellow signal is displayed to them during this period. Otherwise the clearance period is all red.

A maximum period limits the time that moving traffic on either street can maintain its right-of-way against waiting cross traffic.

Section 242.—One-Way Restricted Zone Control

Full traffic-actuated control equipment is available for use at a narrow passage, such as a bridge or tunnel, which is not wide enough to allow traffic to flow in opposite directions simultaneously. This control operates essentially as a full traffic-actuated two-phase control, each approach being one phase, with an all-red clearance period added to the normal cycle. Traffic moves in one direction on one phase and in the opposite direction on the other phase. Between

these movements the all-red interval provides time for clearance of such traffic as may be in the restricted area.

Section 243.—Detectors and Controllers

Since the traffic-actuated signal, as its name implies, responds to vehicle or pedestrian actuations by providing Go indications for the appropriate movements, it is necessary that detector and controller equipment be designed for this service. In this respect, traffic-actuated signals differ considerably from fixed-time signals, which require no detector units and a somewhat simpler timing mechanism for their control. The design characteristics of the various types of detectors and controls that have been developed for use with traffic-actuated equipment are described below.

Section 244.—Types of Detectors

A wide variety of detectors can be used with traffic-actuated signals. These are classified as follows:

1. Pressure-sensitive detectors.
2. Magnetic detectors.
3. Sound-sensitive detectors.
4. Light-sensitive detectors.
5. Pedestrian push-button detectors.

Some of these offer special advantages for particular physical and traffic conditions, and the type of detector should therefore be selected with care. To aid in this selection, the characteristics of the several types are outlined below.

Section 245.—Pressure-Sensitive Detectors

Pressure-sensitive vehicle detectors are of two general types. The most common type is actuated when crossed by vehicles traveling in any direction. In the other type, used principally on narrow two-way roadways, actuation occurs only when the detector is contacted by vehicles traveling in one direction. A brief explanation of the two types follows:

Nondirectional detectors.—Detectors of the nondirectional type operate on the open-circuit principle, with electrical contact established only at the moment that vehicle wheels pass over the rubber surface.

Directional detectors.—With directional type detectors, vehicle impulses are passed into the signal controller from traffic in one direction only, impulses being rejected from traffic moving in the opposite direction. While similar in appearance to nondirectional detectors, the directional type contains two separate sets of electrical contacts, rather than one.

Section 246.—Magnetic Detectors

Magnetic detectors are available in two general types: (1) non-compensated, which have a wide zone of influence; and (2) compensated, which have a sharply defined zone of influence. They are not rendered inoperative or continuously operative by parked cars or by other fixed metal objects within their zone of influence.

Noncompensated detectors.—Noncompensated magnetic detectors are mounted in or under the roadway surface and are usually capable of providing a road coverage up to about 15 feet on either side of the detector. They are not recommended for use at locations subject

to severe and fluctuating electromagnetic influences such as are caused by streetcars and trolley busses.

Compensated detectors.—Detectors of the compensated magnetic type involve two magnetic circuits and are so designed that their operation is not affected by extraneous electromagnetic influences. They are characterized by a relatively sharp definition of their zone of influence, usually extending only about 6 inches beyond each end of the detector. A further characteristic of the best detectors of this type is that they are capable of a high degree of directional discrimination and can, therefore, be used to detect vehicles by lanes of travel.

Section 247.—Sound-Sensitive Detectors

Detectors of this type consist of a hollow metal chamber with a steel top plate and are actuated by sound waves set up in the chamber by the passage of a vehicle wheel over the top plate. These detectors are not affected by ordinary external noises not associated with the passage of wheels over their surface. They are not directional.

Section 248.—Light-Sensitive Detectors

The passage of a vehicle can be detected by the interruption of a beam, or beams, of light between a light source and a photoelectric cell or cells. Sequential interruption of two beams of light can be utilized to provide directional detection.

Section 249.—Pedestrian Push-Button Detectors

In addition to detectors for registering the demand of vehicles approaching an intersection, it is in many instances desirable that means be provided for registering pedestrian traffic demand. Pedestrian push buttons are used for this purpose and are properly regarded as a form of detector. In order to be suitable for traffic-actuation purposes, a push button must be designed to withstand rigorous service.

Section 250.—Types of Controllers

Because traffic conditions are subject to wide variation, it is necessary that traffic-actuated controllers have sufficient flexibility of operation to meet all normal conditions and as many others as possible. Ready adjustments of various time intervals over wide ranges should be possible.

In traffic-actuated controls, Go signal intervals for the approaches with actuation have an initial portion, to permit standing traffic to get into motion, which is followed by one or more unit extensions, the number and duration of which are determined by the traffic itself, within the timing limitations pre-set on the controller. A maximum period protects waiting cross traffic against undue delay in the event that traffic on the other street is very heavy. Clearance intervals are provided at the end of the Go interval.

In semi-traffic-actuated control, the Go interval is normally accorded to the main street, being called to the cross street upon actuation by cross-street traffic. The cross street has an initial portion, which may be followed by an extension portion if cross-street traffic requires. The main street, not having actuation, has only one predetermined period, namely, the minimum period. At the end of this minimum period the Go indication can again be transferred to the cross street in response to actuation. The main-street minimum period should therefore be

set at a value to take care of the expected normal main-street traffic.

All these portions, intervals, and periods should be readily adjustable by suitable knobs, pins, or dials which will require the use of no tools. The limits between which they should be adjustable for the various types of control are presented below in sections 251 to 256.

The ranges of timing adjustment shown are desirable, but in actual operation the adjustment of Go intervals within the range provided should always be made with a view toward safeguarding pedestrian movements, as well as to facilitate vehicle traffic.

Section 251.—Two-Movement, Semi-Traffic-Actuated Controller with Time Extension

For this type of control the interval timing should be adjustable within the following limits:

	<i>Seconds</i>
Main-street minimum period.....	10-90
Clearance intervals.....	2-10
Cross-street initial portion.....	2-12
Cross-street extension limit.....	2-12
Cross-street maximum period.....	10-60

Section 252.—Two or More Movements, Full or Semi-Traffic-Actuated Controller with Time Extension

The various intervals in two-, three-, or four-phase controls, in phases susceptible to extension by traffic actuation, should be adjustable between the following limits:

	<i>Seconds</i>
Maximum period.....	10-60
Initial portion.....	2-30
Extension limit.....	2-30
Clearance interval.....	1-10

Phases not having extension by traffic actuation should have minimum green signal intervals adjustable between 10 and 90 seconds on the main streets and between 10 and 60 seconds on minor streets.

Section 253.—Traffic-Actuated Speed Control for Nonintersection Locations

Nonintersectional speed controls such as may be used on a curve or at a school zone, narrow underpass, or other roadway hazard should have intervals adjustable between the following limits:

	<i>Seconds</i>
Vehicle approach period.....	1-10
Extension limit.....	1-10
Vehicle indicator period.....	3-30

Section 254.—Two-Movement, Full or Semi-Traffic-Actuated Controller With Speed Control

This is the type of controller used at intersections of two streets where excessive speed on one of the streets is an important factor. The various intervals should be adjustable between the following limits:

	<i>Seconds</i>
Maximum period.....	10-60
Initial portion.....	2-30
All extension limits.....	1-10
All clearance intervals.....	1-10
All vehicle approach periods.....	1-10

Section 255.—Two-Movement, Full Traffic-Actuated Controller With Automatic Adjustments of Periods With Respect to Traffic Volume, Relative Density, and Elapsed Time

In this type of control the various intervals and actuations should be adjustable between the following limits:

Minimum initial portion.....	seconds..	5-60
Increase of initial portion per car.....	do.....	0.1-2
Number of cars before minimum initial portion starts to increase		
	cars..	5-50
Passage period.....	seconds..	5-15
Minimum time to which extension limit can be reduced.....	do.....	1-10
Waiting time to reduce extension limit to minimum.....	do.....	10-90
Number of waiting cars to reduce extension limit to minimum.....	cars..	5-40
Density of traffic into green signal (number of cars per 10 seconds to reduce extension limit to minimum).....	cars..	5-40
Clearance interval.....	seconds..	1-10
Maximum period.....	do.....	10-90
Carry-over effect.....	percent..	10-90

Section 256.—Two-Phase, Full Traffic-Actuated Control for One-Way Restricted Zone

With this control the initial portions, extensions, and usual yellow clearance intervals, as well as the maximum intervals, should be timed in accordance with the usual procedure given heretofore. In addition, the all-red clearance interval, during which traffic that has entered the restricted area during the display of the Go signal is allowed to clear, should be adjustable between the limits of 10 and 70 seconds.

Section 257.—Additional Flexibility for Controllers Used in Coordinated Systems

Where a series of intersections along a main street equipped with traffic-actuated control, using actuation on the cross streets only, are to be coordinated, the equipment may be such that the time at which each control can respond to a cross-street actuation is determined by a master timer, or by a local synchronous motor timer.

Section 258.—Provision for Manual Operation

Manual operation of traffic-actuated signals is not generally recommended. The wide flexibility of operation they afford is usually adequate to care for varying traffic demands. However, where traffic conditions are so variable as to make normal operation of the signals inefficient and undesirable at certain times, switches for manual operation of the controller may be provided. Such switches should not be accessible to police officers who are not especially trained and experienced in the direction and control of traffic at intersections.

When the control is being operated manually, actuation of the manual control push button causes the signals to change their indications to those normally displayed in the next interval. Signal display will then remain unchanged until the manual control push button is again actuated.

Section 259.—Installation of Traffic-Actuated Signals

The installation of signal heads, controllers, and certain other elements of traffic-actuated signals involves the same considerations as

those described in sections 175-187, applicable to all signals. Details of the location and installation of vehicle detectors, however, deserve special explanation because of their importance to the efficient and reliable operation of traffic-actuated signal equipment.

Section 260.—Distance of Vehicle Detectors From Stop Line

The proper location for vehicle detectors in relation to the Stop line depends upon the type and operating characteristics of the controller, the speed of vehicles approaching the intersection, physical characteristics of the roadway (grades, widths, parking, visibility, etc.), and special signal functions (turns on separate intervals, stopping side-road traffic before entrance to high-speed artery, etc.). With conventional full and semi-traffic-actuated controller equipment used under average conditions—i. e., level roadway, not more than two traffic lanes in each direction, and good visibility—good results have been obtained when the distance from the Stop line to the detector is related to the speed of approaching vehicles ¹⁰ as follows:

Speed (miles per hour) :	Distance from stop line (feet)
Less than 20.....	110
20-30.....	140
30-40.....	170
40-50.....	210
Over 50.....	225

When the approach to the intersection is on a grade, the distance from the Stop line should be increased about 4 percent for each 1-percent down grade and decreased about 4 percent for each 1-percent up grade. Where there are more than two lanes approaching the intersection, and visibility is not restricted, it has often been found desirable to increase the above distances by small amounts, since higher speeds through the intersections usually can be allowed with safety. The increased distances in such cases may be as much as 15 percent greater than the average values given above. Under no condition should detectors be located less than 40 feet from the Stop line. Where they are installed to permit left-turn movements on a separate signal interval, detectors are usually placed much closer to the intersection than for the control of normal traffic. Where a minor road intersects a high-speed route, it may be desirable to force most cars on the side road to stop before entering or crossing the artery. In such cases, the spacing of detectors should be shortened on the side street so that most cars will arrive at the Stop line on a red signal.

Bus stops, filling-station drives, and other special conditions near an intersection may necessitate the installation of a second detector very near the Stop line. Such installations would in no way interfere with the spacing of the initial detectors of the street so affected.

Speed-control signals normally require longer spacings between detectors and Stop lines, so that desired speed reductions can be achieved gradually and stops required only in cases of abnormally high speeds, or at intersections when right-of-way has been assigned to the cross street. For normal roadway and traffic conditions, when speed-control features are provided, the recommended distance from the Stop line

¹⁰ Eighty-five percent of vehicles approaching the intersection at or below given speed at approximate point of detector location.

to the detector as related to the speed of approaching vehicles ¹¹ is as follows:

Speed (miles per hour) :	Distance from stop line (feet)
20-30 -----	190
30-40 -----	220
40-50 -----	265
50-60 -----	325
Over 60 -----	350

These values should also be increased or decreased, as explained previously, to accord with roadway grades, visibility, and special traffic conditions. Where speed control is applied at an intersection, the above values should be used in locating detectors on the artery and those previously given for standard traffic-actuated control should be used in locating the detectors on the side road.

Detectors for use with two-movement, full traffic-actuated controllers with automatic adjustment of periods with respect to traffic volume, relative density, and elapsed time should be located farther from the Stop line than would be the case with other types of traffic-actuated control. This enables the control to recognize the presence of platoons of cars and in general to get the complete data on traffic conditions necessary to regulate its refinements of control. For normal roadway and traffic conditions, the recommended distance from the Stop line to the detector as related to the speed of approaching vehicles ¹² is as follows:

Speed (miles per hour) :	Distance from stop line (feet)
20-30 -----	240
30-40 -----	270
40-50 -----	320
Over 50 -----	375

For special roadway conditions these values may be changed as recommended for other types of installations discussed above. Where the greatest coordination effect is desired between a series of intersections, the detector spacings on the street on which through movement is desired should be increased about 20 percent.

Section 261.—Location of Vehicle Detectors From Center Line

Pressure-sensitive and sound-sensitive detectors should be placed transversely in the roadway so that all vehicles approaching the intersection cross them with one or more wheels. No vehicle moving away from the intersection should normally cross the detector. When physical conditions are such that more than an occasional car leaving the intersection crosses the detector, a directional detector should be installed so that this traffic will not actuate the controller unnecessarily.

The end of the pressure-sensitive detector nearest the center line of the road should usually be placed about 3 feet therefrom. If the approach side of the road requires more than one detector to cover it satisfactorily, the detectors should be spaced so that the end of the rubber surface of one will be 4 feet from the next. This will insure that no car can pass between the detectors without causing an actuation.

¹¹ See footnote 10, page 151.

¹² Ibid.

In the case of pressure-sensitive detectors, consideration must be given to parked vehicles. In areas where curb parking is allowed, detectors should never be located so that a properly parked car can stand with a wheel on the detector. On one-way streets, the entire roadway should be given detector coverage, except as spaces may be necessary from each curb for parking.

The compensated type of magnetic detector should be buried in the road with the end nearest the center line approximately 4 feet therefrom. If additional compensated magnetic detectors are required to cover the distance to the curb, they should be spaced so that their ends will be about 4 feet apart. The compensated magnetic detector has a rather sharp cut-off and, in general, a vehicle must pass either over it or within 6 inches of its end to cause an actuation.

The noncompensated type of magnetic detector does not have as sharp a cut-off as the compensated type. Its zone of influence is not so clearly defined. It should, therefore, be located under the path traveled by the right wheels of a car traveling in the center of the lane to be covered. A noncompensated magnetic detector can usually be adjusted to cover about 25 feet of roadway. In special cases noncompensated magnetic detectors may be located in or on the shoulder of the roadway.

Light-sensitive detectors, employing photoelectric cells and light beams across the roadway, are normally used only at special locations such as bridges and tunnels. They must be mounted so as to detect the approach of vehicles by having the light beam interrupted by the passing cars. The beams may be in either a vertical or horizontal plane, but if mounted in the open, consideration must be given to snow and ice conditions if the beam is used in a vertical plane. Parked cars would seriously handicap their use in many places.

Section 262.—Installation of Pedestrian Detectors

Pedestrian detectors or push buttons are available for mounting on either wood or steel poles. They should be conveniently located near each end of cross walks used by pedestrians at the roadway location controlled by the signal. The detector should be $3\frac{1}{2}$ to 4 feet above the sidewalk and in view of persons using the cross walks. Permanent-type signs should be mounted just above the detectors, explaining their purpose and use (sec. 52).

When pedestrian detectors are provided for special purposes, such as at school crossings, and are to be used only by authorized persons, lock switches should be installed so that the detectors can be operated only by persons with keys. Such detectors are not intended for the use of the general public and the supplemental signs are not necessary.

Section 263.—Installation of Streetcar Detectors

When streetcars operate on streets where traffic-actuated signal equipment is installed, it is necessary to provide special devices to detect the approach of the streetcars. The distance of detectors from the Stop line is usually determined in the same manner as that for vehicle detectors. However, when streetcar stops or other conditions make it necessary, the spacing between the streetcar detectors and the Stop line may be shortened, or a second detector may be provided on each approach to the signal.

Section 264.—Operation and Adjustment of Traffic-Actuated Signals

As with all types of signals, it is necessary that appropriate equipment be installed to meet the normal traffic requirements of a given roadway location. Assuming the availability of the proper equipment, it is still necessary to adjust and operate the equipment as nearly in accordance with the needs of vehicular and pedestrian traffic as is possible.

Section 265.—Continuous Operation

Traffic-actuated signals of all types should be operated at all times as Stop-and-Go devices except:

1. As a caution signal (flashing yellow) when interconnected with other signals and/or remotely controlled for emergency vehicles such as fire trucks; or
2. As a caution signal, or as a combination caution and Stop signal (flashing yellow on certain approaches and flashing red on others) when failure of controller, wiring, or signal lamps prevents normal operation.

Since traffic-actuated signals, properly timed, cause a minimum of unnecessary delays, there is no justification for changing them to flashing operation during light traffic periods. Right-of-way is normally denied approaching motorists only when intersecting streets are in use by others or when safe approach speeds are exceeded.

Section 266.—Time Intervals and Adjustments

In order to obtain the greatest efficiency from traffic-actuated equipment, the correct setting for the various time intervals must be determined. This often requires some trial and experimentation after the installation has been made. The following explanation is intended as a guide for those not thoroughly acquainted with the general principles and terminology associated with the operation of traffic-actuated equipment. It is suggested that reference also be made to the glossary of signal terms on page 205.

In general, it will be desirable for a person not familiar with such time intervals and adjustments to secure the advice of an experienced representative of the company that manufactures the equipment or of some other well-informed person, until the desired settings and adjustments are well understood. It should be added that these settings and adjustments sound more complicated than they are found to be with experience.

The minimum Go signal interval on a street having traffic-actuated control with time extension includes an initial portion followed by a unit extension. If there is a line of cars crossing the detector after the initial portion has expired, each car crossing the detector will cancel the unexpired remainder of the previous unit extension and initiate a new unit extension. Thus ten cars successively extending the Go period will not necessarily cause the Go signal to remain on that street for ten times as long as one car would. The Go signal will be transferred to the cross street, if there is waiting traffic thereon, following the expiration of the last unit extension.

From the foregoing explanation it can be seen that the unit extension represents the time spacing between cars approaching the green light in excess of which it is desired that the right-of-way be yielded to waiting cross traffic.

Since traffic-actuated equipment controls permit considerable flexibility in the selection of the Go period, extreme care must be used to safeguard pedestrian movements by provision of a minimum length of Go interval which will accommodate the slower pedestrians.

The various settings and adjustments necessary for operation of traffic-actuated controls are as follows:

Initial portion.—The initial portion should be adjusted to a time which, added to a unit extension, will permit a solid line of cars between the detector and the Stop line to clear the intersection.

Unit extension.—The unit extension should be set so that a car which has actuated the detector, if it is traveling at a speed normal for the street, will clear the intersection before losing the right-of-way.

Maximum period.—The maximum period is brought into play only when continuous traffic prevails and cross traffic waits. The point to be considered in setting it is that, when traffic becomes very heavy on both streets, the signal operates, in effect, as a fixed-time signal, and the maximum period determines the proportion of time to be allotted to each street.

Clearance interval.—The clearance interval is set at a value that will permit moving traffic to come safely to a halt when a Stop signal is displayed.

Vehicle approach interval (speed control of the nonintersectional type).—This interval should be set at such a value that a car moving at a speed considered safe for the location will receive the Go signal in time to permit continuing at that rate of speed. Cars approaching at a greater speed will be forced to reduce their speed before proceeding.

Vehicle approach interval and unit extension (speed control with intersectional control).—The vehicle approach interval and the unit extension should be set in accordance with the foregoing suggestions. The maximum period on the main street should be set in accordance with the suggestions previously given for adjustment of the maximum period. Cross-traffic periods (not speed monitoring) should be adjusted as in any traffic-actuated control with time extension.

Interval adjustments for volume-density controllers.—The minimum initial portion should be set at a value that will permit a few cars to pass through the intersection before its expiration. A larger number of vehicles will need more time than this minimum initial portion and since the detectors are far enough away from the intersection so that a large number of vehicles can be between the detector and the intersection, provision must be made for lengthening the initial portion. The number of cars that can pass the detector before the minimum initial portion starts to increase should be the number that can move into the intersection during the minimum initial portion. Each car above this number will cause an additional time to be added to the minimum initial portion. The amount of time added by each car is called "increase of initial portion per car" and should be set at such a value that, under heavy traffic conditions, waiting cars will clear the intersection before the expiration of the minimum initial portion plus the increase thereof. Streetcar and bus actuations are sometimes weighted so as to affect the controller in the same manner as would several passenger automobiles.

The passage time should be set at a value that will permit a car crossing the detector on the green indication to clear the intersection before the expiration of that green indication if the vehicle is moving at a reasonable speed. This can be set long, because if traffic conditions are such that this long period should not be granted, a shorter period determined by requirements of traffic will automatically be substituted therefor.

In this type of control the timing is responsive to several traffic conditions, including the following:

1. Number of cars waiting on cross street.
2. Time that cross traffic has been waiting.
3. Time spacing of vehicles on street with Go signal.

As the number of cars waiting at the red indication increases, the duration of the unit extension on the street having the Go signal is simultaneously decreased, thus requiring denser traffic in order to hold the Go signal thereon. As the number of cars waiting at the red light increases, the extendible portion on the other street is reduced until the low limit set on the controller is reached. The time to which the extendible portion can be reduced, as well as the number of cars waiting against the red light required to cause such reduction, can be adjusted independently for each street. Thus the control constantly balances the number of cars waiting on the Stop signal against the density of the traffic moving into the Go signal in allocating the right-of-way. A platoon of cars crossing the detector on the main street can reduce the extendible portion of the Go interval on the cross street so markedly that it will secure preferential treatment and pass through the intersection without delay.

The controller also keeps track of the time spacing between cars approaching the Go signal and if cross traffic is waiting gives the Go signal to the other street when some preselected amount of straggling occurs. If the pattern of approach-

ing traffic gives an average spacing between cars of 1 second, the unit extension time on that street is automatically set slightly in excess of 1 second. When the main body of the platoon of cars has passed and cars begin to approach at intervals considerably greater than 1 second (in other words, to straggle), the right-of-way will be transferred to the cross street, if traffic is waiting there. If the average time spacing of cars approaching the Go signal is 2 or 3 seconds, the control will automatically set the unit extension at slightly greater than 2 or 3 seconds, again operating to transfer the right-of-way when straggling occurs if there is waiting cross traffic. This effect is adjustable on two dials. One of these sets the minimum time to which the extension limit can be reduced by the rate of traffic flow, and the other sets the rate of traffic flow which will reduce the extension period to the set low level. Until the low level is reached, the more frequent the approaching traffic on the Go signal, the shorter the extendible portion for that indication will become.

The features described above work together to recognize both the approach and clearance of a platoon of vehicles and to operate the signals so as to facilitate these movements.

Intervals for one-way restricted zone controls.—The timing of the initial portion, the unit extension, and yellow clearance interval is the same for a one-way restricted zone signal control as in any traffic-actuated signal having extendible portions. The all-red clearance interval should be set at a value that will permit a car which has crossed the detector to clear the restricted area before the Go signal is given in the opposite direction.

Section 267.—Interval Sequence

Traffic-actuated intersection controllers should provide time intervals for any desired combination of signal indications. The sequence of intervals for each traffic phase should be fixed so that the various intervals will always appear in order when the signal indications on that phase are changed.

Equipment for standard traffic-actuated control (speed control excluded) at intersections should provide any of the standard color sequences. Sequences are limited by the number of intervals available in the controller and the wiring of the controller to the signal heads, so that they are fixed except as they can be changed by rewiring or, of course, by the replacement of the controller.

Interval sequence for traffic-actuated speed control signals can be varied for the application. Typical sequences provide for a normal red indication which changes to green, yellow, or flashing yellow after termination of a vehicle approach period. After the expiration of an extension period, or periods, the signal indication automatically returns to red.

Speed control with traffic actuation at a two-movement intersection causes the signal to operate as a modified three-phase signal. Two of the phases correspond to the two approaches of the speed-controlled street and these may, of course, operate in unison. The third phase handles the cross street.

Controllers actuated by pedestrian detectors may provide distinct pedestrian intervals, with WALK and WAIT indications, as a part of the signal sequence, or they may simply provide a green indication for the street being used by the pedestrian in the same manner as would actuation by an automobile of a vehicle detector on that street.

Section 268.—Rotation of Phases

The rotation of intervals with traffic actuation is determined by demands of vehicles and pedestrians. With simple two-phase operation, the various color sequences are provided in fixed order as the controller responds to the actuation on the two streets. While the

sequence of intervals is always the same, the duration of intervals is governed by traffic demands.

With three- or four-phase operation, intervals for each phase will be initiated only when the demand exists, and the duration of intervals is governed by traffic demand. If there is no demand for one of the phases, that phase is omitted in the rotation of phases.

F—SPECIAL PEDESTRIAN SIGNALS

Section 269.—Definition

Special pedestrian signals are highway traffic signals erected for the exclusive purpose of directing the pedestrian to take some specific action.

Section 270.—Warrants

Special pedestrian signals should be installed in conjunction with traffic signals already meeting one or more of the minimum warrants previously set forth in the sections on fixed-time or traffic-actuated signals (secs. 207–213, 234, 235), under the following conditions:

1. When pedestrians and vehicles move during the same phase and the pedestrian volume crossing the major street averages at least 500 persons per hour for any 8 hours of an average day; or
2. When a separate phase is provided for pedestrian movement in all directions (as at a T intersection or traffic circle), all vehicles being stopped; or
3. When heavy vehicular turning movements require a separate pedestrian indication for the protection and convenience of the pedestrian desiring to cross the street; or
4. When pedestrian movement on one side of an intersection is permissible while through vehicular traffic is stopped to protect a turning movement on the other side of the intersection; or
5. When a separate phase is made available for pedestrians in the operating cycle of a traffic-actuated signal; or
6. When a traffic signal is installed solely for the benefit of pedestrians, as at a factory entrance or a school crossing, even though the volume in warrant No. 1, above, is not equalled or exceeded.

Special pedestrian signals should not ordinarily be installed at school crossings where schoolboy patrols can be used effectively or where students can be directed to cross at locations already controlled by signals or police officers. However, they may be warranted at an intersection used as a school crossing under the following condition:

When minimum vehicular volume entering an urban intersection from all directions averages 600 or more vehicles per hour for the opening and closing hours of school, and minimum pedestrian volume crossing the urban major street averages 100 or more persons per hour during the opening and closing periods of the school. The rural warrant is 50 percent of the foregoing urban volumes.

Other conditions, any one of which may warrant special pedestrian signals at a midblock school crossing, are as follows:

1. When intersections adjacent to the school are more than 1,000 feet apart; or
2. When two lanes or more of traffic in an urban area are moving at average speeds of 25 m. p. h. or greater, during the opening and closing periods of school, and students are required to cross these lanes; or
3. When two lanes or more of traffic in a rural area are moving at average speeds of 35 m. p. h. or greater, during the opening and closing periods of school, and concentrations of students are required to cross these lanes; or
4. When a sharp vertical or horizontal curve or a view obstruction, or a combination of these, exists adjacent to the school crossing, and creates a serious hazard.

In connection with signals installed for school crossings, it should be understood that the signal is not the only remedy nor is it necessarily the best solution to the perplexing problem of traffic conflicts between vehicles and school children. Brief periods during which the hazards are unusually high may often be better handled by officer control. In some circumstances, the pupils' respect for traffic signal indications may be so low as to make the installation of a signal a contributory factor in increasing rather than decreasing accidents. The obedience response to officer control is usually less uncertain. Complete facts should be obtained and studied by competent traffic engineering authorities before decisions are made on special school signal installations.

Section 271.—Type of Control

The control of pedestrian signal indications may be accomplished with the timing mechanism normally employed with traffic signals, in which case the pedestrian phase or indication is given at a predetermined point during each cycle; or the control may be such as to permit the use of a push button to introduce the pedestrian phase or indication in accordance with the needs of pedestrian traffic.

As a general rule, the installation of signals at midblock locations adjacent to schools is to be avoided. However, when such signals are required by some unusual condition, the traffic-actuated type of control should be employed.

Section 272.—General Design Requirements

Special pedestrian signals should meet with three important conditions:

1. They should be located directly in the line of vision of each crossing of pedestrians in either direction.
2. The signal indications should attract the attention of and be clearly readable or understandable to the pedestrian both day and night and at all distances from 10 to 150 feet.
3. The signal indications must be such that they will not be mistaken as vehicle indications by motorists.

The two types of design described below for pedestrian control signals are approved as standard:

1. Two sections of the standard traffic signal face, one lens of which contains the word WALK, the other lens of which contains the word WAIT. (See fig. 25 for details of the WALK lens developed by the Institute of Traffic Engineers. The design of a typical WAIT lens having a dark orange glass is also shown in figure 25. There is no generally accepted pattern for this lens as yet.)

2. A rectangular box-type signal in which the words WALK and DON'T WALK are displayed in red neon lights.

A WALK signal shall always be accompanied by a WAIT or DON'T WALK indication. Particular care should be given to the design and construction of the neon type of pedestrian signal so that in case of an electrical or mechanical failure of the word DON'T, the word WALK will also remain dark.

Lenses should carry letters at least 3 inches high, so designed and spaced as to give a maximum of legibility. Figure 26 shows a WALK and WAIT installation that has proved to be effective. In order to avoid possible confusion to vehicle drivers, letters should appear illuminated on a black background.

Special pedestrian signals are not as yet in extensive use and experimentation with their design details, subject to the conditions stated above, is desirable.

Section 273.—Meaning of Indications

Indications in special pedestrian signals should have the meanings ascribed to them in this section and no other meaning. These meanings are in accord with those set forth in Act V of the Uniform Vehicle Code (sec. 35).

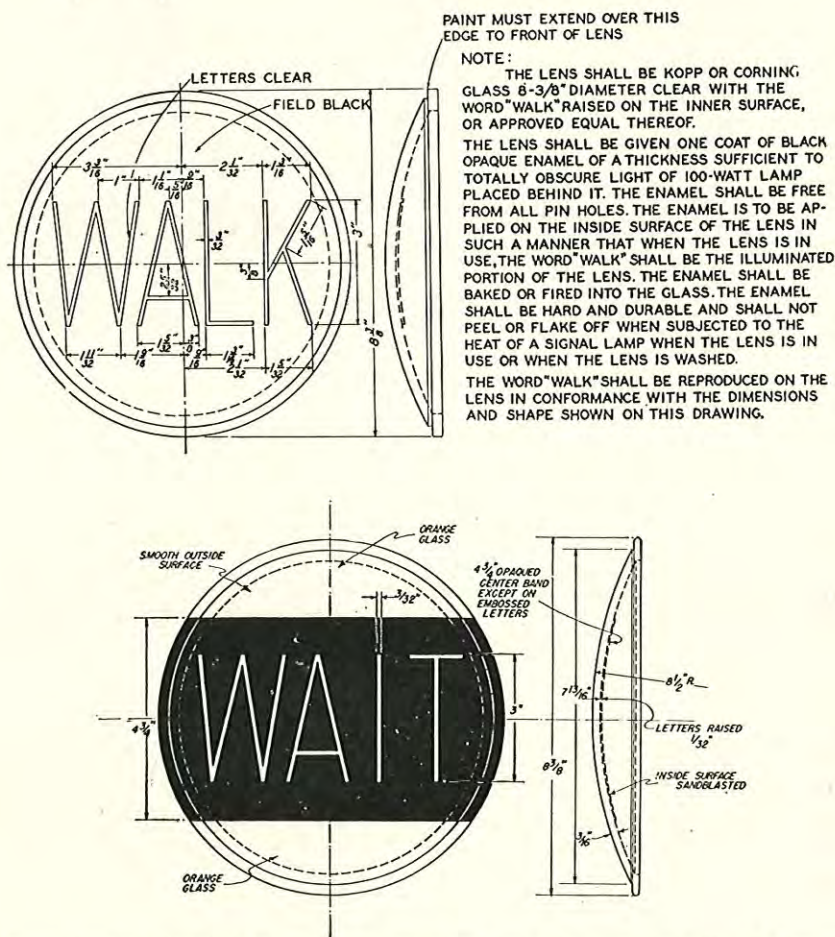


Figure 25.—(ABOVE) WALK lens design; Institute of Traffic Engineers. (BELOW) A typical WAIT lens design.

WALK.—While the WALK lens or indication is illuminated, pedestrians facing such signal may proceed across the roadway in the direction of the signal and shall be given the right-of-way by the drivers of all vehicles.

WAIT or DON'T WALK.—While the WAIT or DON'T WALK lens or indication is illuminated, no pedestrian shall start to cross the roadway in the direction of such signal, but any pedestrian who has partially completed his crossing on the WALK signal shall proceed to a sidewalk or safety island, if one is provided, while the WAIT or DON'T WALK signal is showing.

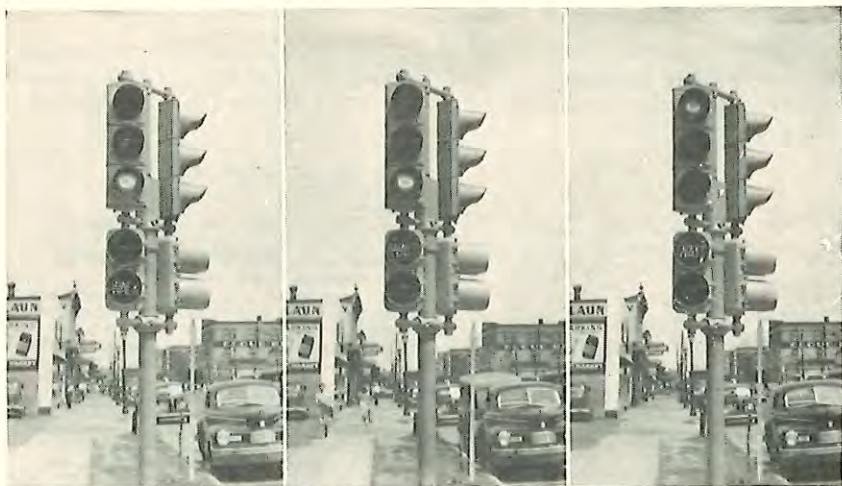


Figure 26.—WALK-WAIT signal installation.

Section 274—Location

Special pedestrian signals should be mounted on corner posts with the bottom of the signal not lower than 7 feet nor more than 10 feet above the sidewalk level and so that there is a signal in the line of vision of each crossing of pedestrians in any direction. These signals may be mounted separately or with the traffic control signals.

Signals installed at midblock school crossings shall follow the usual location standards except that post-mounted signals shall be located 15 feet in advance of the marked cross walk and on the right-hand side of the street. A Stop line shall also be provided.

Section 275—Operation

Most of the general requirements relating to the operation of highway traffic signals apply to the operation of special pedestrian signals as well. It may sometimes be that the need for a separate pedestrian phase will diminish considerably before vehicular volumes drop to a point where flashing operation would be employed. In such cases, it may be desirable to add the time normally allotted to the pedestrian phase to the main-street green interval during this interim period.

Section 276—Phases and Intervals

The length in seconds of phases and intervals provided for special pedestrian signals is normally determined by those allotted to vehicular traffic in the operation of fixed-time or vehicle-actuated traffic signals. When the average walking time required for the pedestrian to cross the roadway is greater than the time necessary for vehicular traffic to clear, however, the former should govern the length of the pedestrian WALK interval, and the vehicular interval should be adjusted accordingly. Since the pedestrian, as well as the vehicle, requires a clearance interval, the period during which it is not possible to start and complete a crossing at the normal walking speed should always be recognized by an appropriate signal indication. Such indication should be given the pedestrian sufficiently in advance of the transfer of vehicle right-of-way to prevent pedestrians from being stranded in the middle of the street.

G—OTHER SPECIAL TRAFFIC SIGNALS

Section 277.—Types of Special Traffic Signals

Special traffic signals include :

1. Flashing beacons and signals.
2. Lane-direction traffic signals.
3. Traffic signals at drawbridges.

Flashing Beacons and Signals

Section 278.—Definition and Application

Flashing beacon.—A flashing beacon is a section of a standard traffic signal head or a similar type device having a yellow or red lens in each face, which is illuminated by rapid intermittent flashes.

Flashing signal.—A flashing signal is a standard highway traffic signal in which the yellow or red lens in each face is illuminated by rapid intermittent flashes.

Flashing beacons and signals perform a very useful function at locations where traffic or physical conditions do not justify a conventional type of Stop-and-Go installation. At other special points of hazard, experience has indicated that the flashing beacon or signal is the only device sufficiently conspicuous to identify the hazard to the motorist.

Section 279.—Warrants

The warrants presented herein for flashing beacons and flashing signals differ, since the latter are merely a utilization of an existing traffic signal installation.

Flashing yellow beacon.—The installation of a flashing yellow beacon may be warranted as an advance warning device at an intersection or other location under one or more of the following conditions:

1. Physical obstruction existing in the roadway.
2. Important intersection hidden by an obstruction or sharp curve in the highway.
3. Proximity of a fire station.
4. Sudden change from rural conditions, where relatively high speeds are safe, to those of an urban district where speed must be reduced.¹³

Flashing red and yellow beacon.—The installation of a flashing beacon at an intersection with yellow flashing on the main street and red flashing on the side street or streets may be warranted by one or more of the following conditions:

1. Instead of or in conjunction with Stop and Advisory Speed signs at intersections where sight distance is extremely limited or where other conditions make it especially desirable to emphasize the need for stopping on one street and for proceeding with caution on the other.

This type of installation is especially effective at intersections where approach speeds are in excess of that warranted by conditions, and drivers are not adequately impressed with the need for stopping or reducing speed by the use of standard or oversize Stop signs, by Stop signs and Advance Warning signs, or by Advisory Speed signs.

2. Minimum vehicular volume entering an urban intersection from all directions averages 300 vehicles per hour for at least 2 consecutive hours, of which vehicular traffic entering the intersection from the minor street or streets averages at least 30 vehicles per hour for the same hours. Warrants for rural areas are 50 percent of the above urban volumes.

¹³ The effect of flashing yellow in reducing traffic speed, according to available experience, has not been particularly potent; and care should be taken not to overestimate this value of the flashing yellow indication. The idea is sound, however, and better public understanding and enforcement may eventually prove its worth.

3. Two or more reported accidents in a 12-month period of types susceptible of correction by cautioning and stopping of traffic.

4. Intersection on or at the bottom of a long or steep grade where excessive speed may prevail.

Flashing red and yellow signal.—A combination flashing yellow (Caution) and flashing red (Stop) signal is warranted as part of a signal installation not continuously operated on a Stop-and-Go basis if the volume of traffic falls below the minimums given in sections 208 to 210.

When signals normally operated as Stop-and-Go signals are put on flashing operation in accordance with the above, the color indications given to the several streets should be based on the following considerations:

1. If one of the streets involved is a through street, it should be given a flashing yellow (Caution) indication and the other approaches should be given a flashing red (Stop) indication.

2. If the safe approach speed on one street differs from the safe approach speed on the other street or streets, the street having the higher safe approach speed should be given the flashing yellow (Caution) indication and other approaches should be given a flashing red (Stop) indication.

3. If the safe approach speed on any street in urban areas is below 8 miles per hour, that street, regardless of other considerations, should be given the flashing red (Stop) indication. The corresponding safe approach speed value for rural areas is 12 miles per hour. Other approaches should be given the flashing yellow (Caution) indication.

Section 280.—Types of Control

Types of control used with flashing signals or beacons are as follows:

1. The motor flashing switch, usually installed in the housing of the flashing beacon, is used solely to provide intermittent illumination of the beacon lenses.

2. Where flashing operation of the conventional fixed-time or traffic-actuated signal is desired, the control is provided by an electrical mechanism supplementary to the signal timer. This operates in a manner similar to the motor flashing switch to provide intermittent illumination of the signal lenses.

Section 281.—Design

Flashing beacon and signal units and their mountings shall follow the general design specifications of standard traffic signals, which include the following essentials:

1. Each signal unit lens shall have a visible diameter of 8 inches.

2. The illuminating element, lens, reflector, and visor shall each be of such design as to render the lens, when illuminated, clearly visible to traffic facing the signal at all distances from 10 to 300 feet under all atmospheric conditions, except dense fog, both day and night.

3. The color of the lens shall be red for Stop and yellow for Caution.

All flashing contacts should be equipped with filters for suppression of radio interference.

Section 282.—Location

The particular purpose of a flashing beacon should largely govern its location with respect to the roadway and the hazard or other condition warranting the beacon. If located at the roadside, flashing beacons as measured from the bottom of the signal head should be at least 8 feet above the pavement. If suspended over the roadway, they should not be more than 15½ feet nor less than 14½ feet above the pavement. In no case should they be mounted on pedestals in the roadway unless the pedestal is within the confines of a traffic or pedestrian island.

Section 283.—Operation

The illuminating element in a flashing yellow (Caution) or flashing red (Stop) beacon or signal shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be approximately equal to the nonilluminated period.

Flashing beacons should generally be operated continuously throughout the 24-hour period.

Flashing signals also should generally be operated continuously throughout the 24-hour period, except when conditions warrant their being changed to standard Stop-and-Go operation. In every case, the change from Stop-and-Go to flashing operation should be made during or immediately following the main-street green interval.

Lane-Direction Traffic Signals

Section 284.—Definition and Application

Lane-direction or off-center traffic signals are traffic signals used to control the direction of traffic movement by individual lanes of a street or highway. These installations are distinguished by signal units over each lane of the roadway, and supplementary signs are often used to explain their significance.

Section 285.—Warrants

Lane-direction traffic signals may be warranted when:

1. Vehicular traffic flow in one direction on a two-way street, highway, bridge, or tunnel, having three lanes or more, exceeds the reasonable capacity of the lane or lanes normally used for traffic moving in that direction and, at the same time, traffic flow from the opposite direction does not require the number of lanes which it is generally allocated.

2. Traffic movement at toll-booth areas and single-lane tunnels requires reversal in direction of traffic flow for efficient operation.

3. Traffic movement in one direction at an entrance or exit of a parking lot at an industrial plant, stadium, or similar location greatly exceeds the capacity of the traffic lanes allocated for handling balanced traffic flow.

4. Heavy traffic flow is slowed down and congested on a long uphill grade of a three-lane roadway because of slow-moving commercial vehicles traveling up the hill, thereby warranting the use of two lanes for uphill and one lane for downhill movement.

5. Temporary road conditions reduce the number of lanes normally available to handle traffic movement, even though it is extremely unbalanced at various periods of the day.

Section 286.—Types of Control

The type of control provided for lane-direction signals should be such as to permit automatic or manual operation of the signals. The control mechanism should permit the illumination of the red lenses in both directions in the same lane for those lanes where the traffic flow is subject to being reversed. The possibility of an erroneous indication of green in both directions in the same lane should be avoided by wiring the green signal so that it can be illuminated only when the red signal shows in the opposite direction. Normally, no more than a two-lens signal, having red and green lenses, is required for each direction of traffic, since the signals are not often placed at intersections.

Section 287.—Design

Traffic signal heads used for controlling the direction of movement by lanes shall have two faces. Each face controlling a lane subject to reversing traffic flow shall contain standard red and green lenses and otherwise shall follow the general design specifications of traffic control signals. In lanes not subject to reversing traffic flow signal faces shall have a single lens, red or green, whichever is appropriate for the location. Mountings shall permit the signals to be suspended over lanes on cables or fixed supports.

Section 288.—Location

A traffic signal head with a face for each direction of traffic to be controlled shall be located over the center of each lane of the roadway at the beginning and end of the lane-controlled section. If the area to be controlled is more than 1,000 feet in length, or if the vertical or horizontal alinement is curved, intermediate signal heads shall be placed over each lane at frequent enough intervals so that motorists will at all times be able to see at least two signals along the roadway and have a definite indication of the lanes specifically reserved for their use. At the terminal and intermediate signal installation points on the lane-controlled section, signal heads above the various lanes shall be located in a transverse straight line at right angles with the roadway alinement.

Section 289.—Operation

All traffic signals used to control traffic movement by lanes shall be coordinated and wired to a master control which will operate so as to permit all two-lens signal faces for each direction in any of the reversing lanes to change from red to green or from green to red, except that the showing of green in both directions over the same lane shall be guarded against by electrical interlock. It shall also be possible to show a red indication in both directions in any of the lanes subject to reversing traffic flow. This latter feature permits the establishment of a neutral area or safety zone during light traffic periods or during an emergency traffic situation.

The system shall operate either manually or automatically through the use of a time clock.

Traffic Signals at Drawbridges

Section 290.—Application

Signals installed at drawbridges to control vehicular traffic are a special application of highway traffic signals.

Section 291.—Warrants

Traffic signals should always be used in conjunction with gates and the other types of protection commonly employed at drawbridges.

Section 292.—Design

The traffic signal heads and mountings shall follow the standard design specifications of traffic signals. Drawbridge signals

may be supplemented with bells which operate with the red signal indication to provide additional warning to drivers.

Section 293.—Location

Traffic signals shall be located at both ends of the movable span. To assure positive visibility, two signal heads should be mounted on each approach to the movable span, one on the right and the other on the left side of the roadway. They should ordinarily be not less than 50 feet nor more than 100 feet from the end of the movable span.

Section 294.—Operation

Traffic signals at drawbridges shall be interconnected with the drawbridge gates and, if feasible, with other signals on the same street or highway within 500 feet of the bridge. Not less than 15 seconds before the gates are closed, the signal shall change from green to yellow to red. While the gates are closed and the draw is open, the signals shall show a continuous red indication. After the draw is closed and the gates opened, the indication shall change to a steady green and remain so until the next bridge opening.

If the drawbridge is close to a railroad grade crossing and there is a possibility that traffic may be stopped on the railroad crossing as a result of the bridge opening, a supplementary traffic signal may be required at an intersection on the approaches near the grade crossing. In this event, extreme care should be used in planning the signal lay-out and operation so as to avoid the creation of confusion and hazard to motorists, either at the drawbridge or at the grade crossing. Normally, such installations should be interconnected to provide coordination in signal indications under a given set of conditions.

H—TRAIN-APPROACH SIGNALS AND GATES

Section 295.—Railroad Grade-Crossing Protection

Signs are inadequate protection at railroad crossings where highway traffic is heavy, train movements are frequent, or visibility is seriously obstructed. At such crossings there should be installed train-approach signals to indicate the approach and passage of trains, or gates which will extend into or across the roadway to prevent vehicles from entering upon the crossing while trains are approaching and occupying the crossing. The following sections deal only with signals and gates of the automatic type.

Train-Approach Signals

Section 296.—Classification and Definitions

Train-approach signals are classified as flashing-light or wigwag signals.

A flashing-light signal is an electrically or mechanically operated signal in which indication of the approach of a train is given by two horizontal red lights flashing alternately at predetermined intervals, producing the equivalent of a signal given by a watchman swinging a red lantern.

A wigwag signal is similar to the flashing-light signal except that

the indication of the approach of a train is given by a swinging disk and a red light enclosed in the disk.

Section 297.—Warrants

Train-approach signals shall be installed at railroad-highway grade crossings to warn highway traffic of any approaching train where the volume of traffic of both the railroad and the highway warrants, or where physical obstructions to clear vision exist on highway approaches. Such signals shall be used for no other purpose.

Section 298.—Types of Control

Flashing-light and wigwag signals may be controlled manually, or automatically through track circuits arranged so that the flashing-light signals will operate until the rear of the train reaches or clears the crossing and so that the signals will operate upon the approach of trains from either direction on the tracks for which protection is provided.

Section 299.—Design

Flashing-light signals.—The following provisions relate to the design of flashing-light signals:

1. Signal lights shall shine in both directions along the highway and be mounted horizontally. The distance between centers of lights shall be 30 inches. Lamps shall preferably be not less than 7 feet nor more than 9 feet above the surface of the highway.

2. Lenses or roundels shall be a minimum of $8\frac{3}{8}$ inches in diameter, and shall be in accordance with *Signal Section Specification 69* of the Association of American Railroads.

3. The Railroad Crossbuck sign (sec. 89) and the signal shall be mounted on the same post.

Wigwag signals.—The following provisions relate to the design of wigwag signals:

1. A wigwag signal shall consist of a disk 20 inches in diameter, in the center of which a lamp with red lens or roundel is provided for night indication.

2. The disk shall be supported by a pivoted rod and the length of stroke of the swinging light in the disk measured horizontally between extreme positions shall be 30 inches.

3. Lenses or roundels shall be a minimum of 5 inches in diameter, and shall be in accordance with *Signal Section Specification 69* of the Association of American Railroads.

4. The Railroad Crossbuck sign (sec. 89) and the signal shall be mounted on the same post.

Section 300.—Location

Whichever type is used, one signal shall be placed on each side of the track.

The location of signals for railroad-highway grade-crossing protection should be determined after inspection and study at the site. In addition to providing for adequate clearances, consideration should be given to the type of pavement, angle of crossing, and visibility to drivers approaching the crossing.

Section 301.—Installation

Flashing-light and wigwag signals shall be installed in accordance with the standards as prescribed in *Railroad Highway Grade Crossing Protection*, Bulletin No. 3 (or subsequent issue), Association of American Railroads, Joint Committee on Grade Crossing Protection.

Section 302.—Operation

Automatic signal devices used to indicate the approach of trains shall so indicate for not less than 20 seconds before the arrival of the fastest train operated over the crossing.

Local conditions may require a longer operating time, but too long an operation by slow trains is undesirable. Uniform time control for all train speeds is the most desirable arrangement and at crossings where there is considerable difference between high and low train speeds and where travel on the highway is heavy, provision for a type of circuit control that will insure equal or approximately equal timing should be considered.

Lights in the flashing-light type of signal shall flash alternately. The number of flashes of each light per minute shall be 30 minimum, 45 maximum. Lights shall each burn the same length of time. Total burning time of both lamps shall be practically the entire operating time.

Each flashing-light unit shall provide an indication having a beam candlepower of uniform intensity at any angle up to 10 degrees on either side of the axis, and the range at any point in the 20-degree angle under bright sunlight conditions, with the sun at or near the zenith, shall not be less than 1,500 feet when a 10-watt lamp rated at 1,000 hours is burned at rated voltage.

With the wigwag type of signal, movement of the swinging disk from one extreme to the other and back constitutes a cycle. The number of cycles per minute shall be 30 minimum, 45 maximum.

The signal light of the wigwag signal, when the disk is suspended vertically, shall have a range, at night, of 1,500 feet through a total angle of not less than 30 degrees when a 10-watt lamp rated at 1,000 hours is burned at rated voltage.

Section 303.—Maintenance

Signals shall be kept well painted and in a good state of efficiency. The surfaces of lenses on signal lamps shall be kept free from such deposits as soot or other materials, since these will seriously affect their efficiency.

Railroad-Highway Grade-Crossing Automatic Gates

Section 304.—Application

Automatic gates, where installed, shall be provided as an adjunct to the Association of American Railroads' recommended automatic crossing signals of the flashing-light or wigwag type described above. When indicating the approach of a train they shall present toward the highway in both directions the appearance of a horizontal arm carrying three red lights and extending over the traveled roadway a sufficient distance to cover the lane or lanes used by traffic approaching the crossing.

Section 305.—Warrants

Automatic gates and signals of the type described herein shall be installed at railroad-highway grade crossings to warn highway traffic of any approaching train where the volume of traffic of both the railroad and the highway warrants, or where physical obstructions to clear vision exist on highway approaches. These devices shall be used for no other purpose.

Section 306.—Types of Control

Automatic gates may be controlled manually, or automatically through track circuits. The gates shall reach the full horizontal position before the arrival of the fastest train operated over the crossing and shall remain down until the rear of the train has cleared the crossing, and they shall operate upon the approach of trains from either direction on the tracks for which protection is provided.

Section 307.—Design

The gate arms and housings containing the arm-operating mechanisms shall be mounted on the post supporting the crossing signals and Railroad Crossbuck sign.

The bottom of the gate arms, when in the horizontal or lowered position, shall be not less than 3 feet nor more than 4 feet above the crown of the roadway and, when not indicating the approach of a train, shall neither obstruct nor interfere with highway traffic.

The mechanisms shall be so designed that if the arms, while being raised or lowered, strike or foul an object, they will readily stop and, on removal of the obstruction, shall assume the position corresponding with the control apparatus.

Each gate arm extending over the highway shall have three red lights shining in both directions along the highway. The light nearest the tip shall burn steadily and the other two lights shall flash alternately.

The gate arms shall be painted on both sides with 16-inch alternate diagonal stripes of white and black.

Lenses or roundels shall be in accordance with *Signal Section Specification 69* of the Association of American Railroads.

Section 308.—Location

The location of automatic crossing gates for railroad-highway grade-crossing protection shall be determined after inspection and study at the site. In addition to providing for adequate clearances, consideration shall be given to the type of pavement, angle of crossing, and view when approaching the crossing.

Section 309.—Installation

Automatic gates shall be installed in accordance with the standards prescribed in *Railroad Highway Grade Crossing Protection*, Bulletin No. 3 (or subsequent issue), Association of American Railroads, Joint Committee on Grade Crossing Protection.

Section 310.—Operation

Circuits for the operation of automatic gates shall be so arranged that the gates will start to assume the horizontal position between 3 and 5 seconds after the warning signals start to operate. Gates shall reach a full horizontal position before the arrival of the fastest train operated over the crossing and shall remain down until the rear of the train has cleared the crossing.

Uniform time control for all train speeds is the most desirable arrangement, and at crossings where there is a considerable difference between high and low train speeds and where travel on the highway is

heavy, provision for a type of circuit control that will insure equal or approximately equal timing in the operation of automatic gates should be considered.

Section 311.—Maintenance

Automatic gates shall be kept well painted and in a good state of efficiency. The surfaces of lenses on signal lights on the gate arms shall be kept free from such deposits as soot or other materials, since these will seriously affect their efficiency.

ISLANDS

A—INTRODUCTION

Section 312.—Function of Islands

The term "island" is applied to certain areas within the roadway from which vehicular traffic is diverted by pavement markings or other warning devices, or excluded by physical construction. Such islands are designed to segregate pedestrians and vehicles or otherwise to control streams of traffic in order to minimize conflicts, expedite traffic flow, or increase safety. For the purposes of this manual, an island includes not only the restricted area, but also all end protection or other approach-end treatment.

Previous editions of this manual have dealt with rotary islands (traffic circles). Although rotary islands admittedly are devices for traffic control they are rather to be regarded as basic elements of highway design. The following discussion is confined to traffic control islands that are or can be located in relatively restricted roadway or intersection areas.

For similar reasons, the treatment of divisional islands here applies primarily to urban and suburban installations, where intersections are frequent and the islands are correspondingly discontinuous, rather than to extended median strips in open country.

Certain features of island design, however, such as approach-end treatment and illumination, are to be regarded as generally applicable to all islands, including those of the rotary and divisional types.

The right of a pedestrian to occupy a pedestrian island in safety is commonly protected by law. Act V of the Uniform Vehicle Code (secs. 17, 103) for example, defines a "safety zone" and prohibits motor vehicles from entering a safety zone at any time, regardless of whether or not the physical construction would permit such entry.

Section 313.—General Engineering Requirements

As islands are placed in areas which would otherwise be available for vehicular traffic, they should be installed only after careful engineering study to determine their necessity and value. Islands should be so designed and placed as not to create additional traffic hazards. They should be plainly visible to oncoming vehicle operators, both by day and by night, and accordingly should be of a color contrasting with the street surface. They should be illuminated, signed, and marked as herein recommended, depending on their design and the traffic conditions.

In the determination of type and size of structure or device, consideration should be given to maintenance as well as construction cost. Esthetics should be given full consideration but should not be permitted to decrease the usefulness of the island.

Section 314.—Classification

Islands may be classed functionally and physically as follows:

1. Pedestrian islands:¹⁴
 - (a) Loading islands (secs. 316-330).
 - (b) Refuge islands (secs. 331-344).
2. Traffic islands:
 - (a) Divisional islands (secs. 345-355).
 - (b) Channelizing islands (secs. 356-366).

These several types of islands are illustrated in figures 27-30.¹⁵

Pedestrian islands include all areas in roadways set aside exclusively

¹⁴ See definitions on page 5 indicating relation of pedestrian islands to safety zones.

¹⁵ The photographs in this part of the manual were chosen to illustrate certain features of islands. Other features that appear in the pictures, such as signs, markings, and signals, may vary from the standards set forth in this manual.



Figure 27.—A raised loading island with illuminated metal grill buffer and approach-end pavement marking.



Figure 28.—A refuge island with low marker lights, arrow, and sign. Pedestrians can cross the street without stepping up on this island.

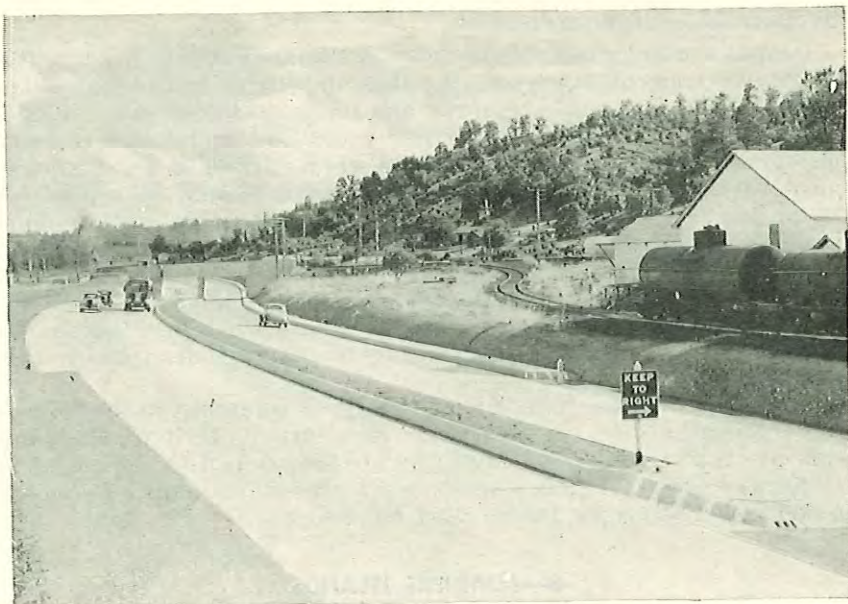


Figure 29.—A divisional island extending from a bridge pier. The approach end is signed, striped, and reflectorized.

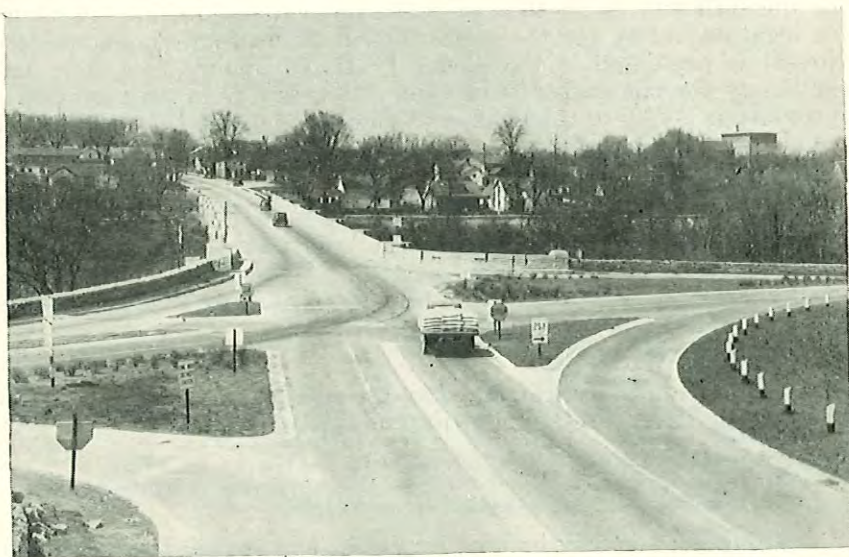


Figure 30.—Channelizing islands at an intersection, with supplementary signs and pavement markings. Concrete curbs delineate the island edges.

for persons on foot. Traffic islands include all areas created for the separation and directing of vehicular traffic. The basic functions of the two groups are different, and they are accordingly treated separately herein. However, an island may serve as both a pedestrian island and a traffic island.

Section 315.—Standardization

Islands are not adaptable to detailed standardization, inasmuch as they cover areas of widely varying sizes and shapes and require adaptation in each case to the roadway and traffic characteristics. This is particularly true with respect to end protection, approach-end treatment, and illumination. This manual sets forth certain basic requirements, based upon present knowledge, which should be considered in the location, design, and construction of islands, certain minimum dimensions that should be observed, and advantages and disadvantages of certain types and designs. Although further study and experimentation is under way in various communities, and should be encouraged, it is recommended that present-needed installations be designed in accordance with the approved practices described in this manual.

Additional information on island design is contained in the following publications of the American Association of State Highway Officials: *A Policy on Highway Types (Geometric)*, *A Policy on Intersections at Grade*, *A Policy on Rotary Intersections*, and *A Policy on Grade Separations for Intersecting Highways*.

B—LOADING ISLANDS

Section 316.—Legal Authority

Loading islands, being in the roadway, can be established only on the authority of the local or State highway authorities. A model of legal authority for the establishment of loading islands (safety zones) is presented in the Model Traffic Ordinance (sec. 51), and authority for the exclusion of vehicular traffic from such islands is provided in Act V of the Uniform Vehicle Code (sec. 103). No other legal authority is involved.

Section 317.—Functions

The main function of loading islands is to afford protection to streetcar riders at loading, discharge, and transfer points, and to riders of busses and trolley busses using such islands. They also expedite traffic by permitting other vehicles to continue in motion while the public vehicles are stopped for loading.

Section 318.—Warrants

Loading islands are warranted and should be established at streetcar stops under any of the following conditions:

1. Where both vehicular and pedestrian traffic are heavy.
2. Where the speed of vehicular traffic along the roadway is relatively high.
3. Where accident experience indicates the need.

Loading islands may be used by busses and trolley busses as well as by streetcars. The chief advantage of this is that it concentrates all of the mass-transportation vehicles in one traffic lane and leaves the other lanes free for vehicles not required to stop frequently. Disadvantages are that bus passengers, having to cross traffic lanes, are deprived of the greater safety of loading at the curb, and that these free-wheeled vehicles which might do their loading at the curb may, while using the loading islands, delay streetcars unable to reach the islands.

When a separate loading place is used by busses or trolley-busses, it should be located at the curb and well away from the loading island, to avoid congestion in the traffic lane beside the island.

Section 319.—Location

Loading islands at street intersections should be extended to the cross walk, unless this is not feasible because of switches, streetcar turning movements, or similar conditions. **They shall not, however, be continued within the cross walk (figs. 27, 31, 32).** Loading islands should in general be located at intersections, but a midblock island may be warranted in a long city block.

In no case shall a loading island be established unless there is at least one adequate traffic lane between the curb and the island.

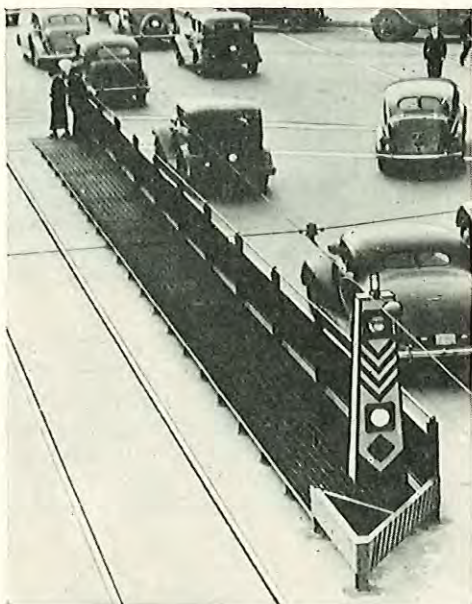


Figure 31.—A raised loading island in a business district, with metal grill platform protected by side rail and metal splash plate. The steel buffer and pylon are striped and illuminated.

Where it is intended to permit automobiles and trucks to pass on the left of islands (sec. 328), such islands, to serve transit vehicles (streetcars or busses) moving in opposite directions, should not be located laterally opposite each other.

Section 320.—Access

Access to loading islands adjacent to intersections and of sufficient length to accommodate four or more transit vehicles should be safeguarded by a marked cross walk from the near sidewalk in addition to the cross walk at the intersection. Midblock loading islands should have at least one marked cross walk from the near sidewalk or across the entire roadway, depending upon conditions.

Section 321.—Elements of Design

Loading islands shall be of a permanent type, and shall be designed to afford the necessary protection to streetcar riders or other pedestrians and at the same time create as little hazard as possible to passing vehicles.

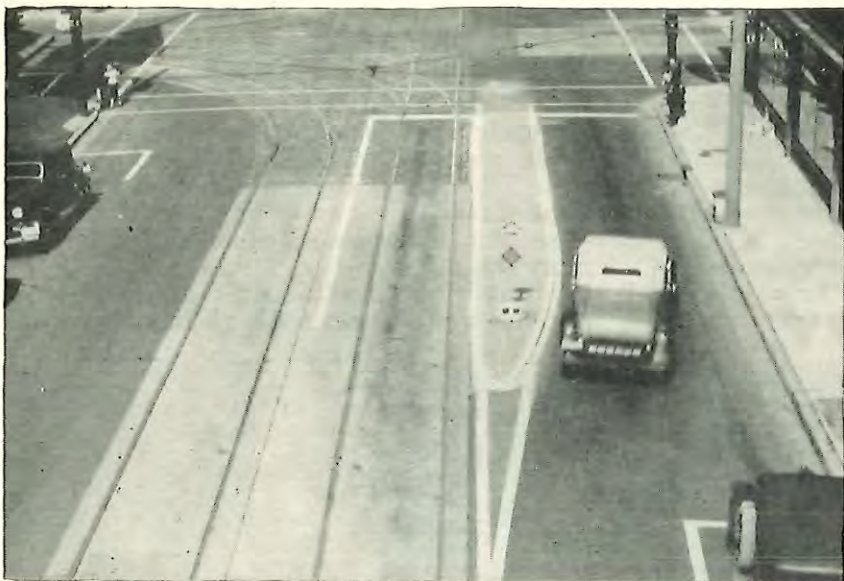


Figure 32.—A raised loading island with highly effective approach-end treatment of pavement marking, painted curb, sign, reflector cluster, and low marker lights. This island has no buffer.

Loading islands will ordinarily have four distinct parts: (1) The area intended to be occupied by pedestrians, (2) a physical barrier at the approach end to prevent motor vehicles from entering the pedestrian area, (3) devices at the approach end to warn vehicle operators of the presence of the island and to direct them into a suitable path or paths past it, and (4) illuminating devices adequate to make all parts of the island clearly visible at night. They may in addition require side protection.

Section 322.—Designation of Area

The pedestrian areas of loading islands are in practice specifically designated either by platforms or by some other means.

Platforms.—Platforms raised above the pavement level to approximately the height of the adjacent curbs and with adequate safeguards (secs. 324–326) afford the best protection to pedestrians (figs. 31, 33, 34).

The platforms are usually permanent structures of concrete or other sturdy materials, with the surface properly sloped for drainage. In some instances, for economy or convenience, they are made of wood. In all cases they should be built substantially and of proper height, and the outside edges should be faced smoothly.

Other means.—Other means of designation in use include rows of fixed posts connected by chains or rails, mushroom buttons, pavement markings, or various combinations of these or other devices (fig. 35).

Platforms are the most satisfactory means of designation, providing the greatest actual protection and the greatest sense of security to pedestrians. Posts and chains or rails are next in order of effectiveness. Islands designated by simple pavement markings, with or without mushroom buttons or portable stanchions but without other protec-



Figure 33.—Posts and chains provide side protection for this raised loading island. The rounded buffer is striped and illuminated for high visibility.



Figure 34.—End protection for this loading island is furnished by heavy metal posts, the center one low enough to allow clear view of the reflectorized cluster. Side protection is provided by posts and chains, set back from the curb. The clean-cut openness of this island permits good visibility.

tion, are dangerous and not recommended except in some business districts where speeds are ordinarily low.

Section 323.—Dimensions

Length and width.—A loading island should be of sufficient length to provide adequate access to entrances for the full number of streetcars or other public transportation vehicles likely to stop at the island at one time in recurring peak traffic.

Loading islands shall be at least 4 feet wide. Where the number of transit vehicles and passengers normally using the island requires,



Figure 35.—A street-level loading island in a business district. The loading area is protected by metal posts with sheet-metal splash plate, and the pylon is striped and illuminated for high visibility.

the width should be greater and sufficient to enable riders to reach the desired vehicle entrances without undue crowding or delay.

Because of the differences in widths of streetcars, no standard distance from the rail can be specified. Platforms should be built to accommodate the narrowest car. If any cars are operated which will overhang the edge of the island, warning to this effect should be given by plainly visible line markings on the surface of the island indicating a safe clearance distance.

Height.—The platform height of a loading island shall be from 5 to 7 inches, except where transit vehicles require a lesser height for clearance, and in general shall conform to local standards of curb height for sidewalks.

Where additional thickness of roadway pavement surfacing is anticipated due allowance should be made for it.

X Section 324.—End Protection

Loading islands outside of congested business districts and wherever feasible within business districts shall, at the end toward approaching traffic, have adequate physical protection in the form of a buffer to withstand the impact of a colliding vehicle. This buffer may be a concrete block, a series of solid posts or pipes, or other massive structure (figs. 27, 33, 34, 36–38).

A concrete block is an effective buffer (figs. 33, 36, 37). It should be sloped or rounded to deflect a colliding vehicle not meeting it head-on, and should be so constructed and marked as to be highly visible. It should be of an attention-arresting color, usually in sharp contrast with the color of the pavement. In addition, effective illumination, reflectors, indented facets, or other high-visibility treatment is recommended. Care must be exercised in the design of concrete

buffers to assure adequate clearances for all types of streetcars in present or prospective use in the community.

Where vertical posts are used, three or more should be set to form a deflecting arc. These may be connected with horizontal members and should be provided with a sheet-steel facing to deflect a vehicle hitting them at an angle.



Figure 36.—A concrete loading island with end protection provided by a rounded concrete buffer. Two alternately flashing lights and an illuminated striped panel warn drivers of approaching vehicles of the island's presence.



Figure 37.—A raised loading island with protection provided by an illuminated and reflectorized buffer with long sloping prow.



Figure 38.—Side protection for this loading island is provided by a concrete panel. The high, massive buffer is a sight obstruction, and equal utility and better appearance could have been obtained by a more open design.

Section 325.—Approach-End Treatment

The approach end of a loading island, whether or not protected by a buffer, shall be carefully designed to provide a maximum degree of warning of the presence of the island and, where necessary, definite indication of the proper vehicle path or paths to be followed.

Various types and forms of such treatment have been used and deemed satisfactory. Experimentation on other forms and on modifications of present forms is developing new possibilities and should be continued. The following devices, which vary greatly in details, are in present use:

1. Pavement markings, with or without mushroom buttons (sec. 330).
2. Signs (sec. 329).
3. Reflecting devices (secs. 152, 156).
4. Flashing yellow beacons (sec. 278).
5. Contrasting pavement colors and textures.
6. Jiggle bars (see definition, page 5).
7. A vertical element sloping up to the island nose.
8. Various combinations of 1 to 7.

Figures 27, 31–38 are typical illustrations of some of the foregoing.

A development of the sloping vertical element is the prow (see definition, page 5). Prows installed to date, with lengths varying from 10 to 40 feet and with wide variations in shape, indicate the need for further study to determine their relative merits and the most effective design (figs. 37, 38).

Whatever the form or forms of approach-end treatment and end protection, their adequate night illumination is vital (sec. 327).

Section 326.—Side Protection

Side protection of loading islands is warranted only where unusually hazardous conditions indicate its need, as where crowds of waiting passengers would otherwise overflow the island, particularly where

a platform is not provided. Such protection should be provided by a line of fixed or firmly secured posts, not less than 3 feet high and set not more than 8 feet apart, connected by chains or rails. The purpose of this is not only to keep motor vehicles off the island but also to keep streetcar and bus riders within the island and discourage crossing between island and sidewalk at other than designated points (figs. 31, 33-35, 38).

In addition to a chain or rail connection of posts for side protection it is desirable to place a substantial sheet of metal along the line of posts, on the side of vehicular traffic, to prevent vehicle wheels from striking the posts, to divert such traffic away from the loading island, and to serve as a splash plate. Such a plate should be of adequate height to serve the intended purpose. Splash plates are particularly advantageous at islands without a raised platform (fig. 35), but also are used in some cities in conjunction with platforms (fig. 31). Where space permits, some form of solid wall may be employed (fig. 38).

When posts without a splash plate are used on raised platforms they should be set back somewhat from the platform edge to lessen the likelihood of being hit by motor vehicles (fig. 34).

Where a cross walk leads to a loading island, any side-protection posts should leave an opening the full width of the cross walk.

Section 327.—Illumination and Reflectorization

All loading islands, including their approach-end treatment, shall be provided with:

1. General illumination of the entire area, including adjacent vehicular-traffic lanes, or as much of the area as is required for safe operation;
2. Intensified illumination and reflectorization to show clearly the outlines of buffers or other structures, collision with which would seriously damage motor vehicles or imperil pedestrians.

Loading islands shall not be installed unless they can be adequately illuminated. It is desirable to have two independent sources of light in case of failure of one.



Figure 39.—Approach-end treatment to give advance warning of the presence of this loading island consists of high and low reflector clusters, yellow-painted curb, and mushroom button.

The effectiveness of approach-end treatment of islands depends greatly upon illumination and reflectorization. There are numerous possible ways of providing these, and the successful devices and combinations of devices suggested herein should not preclude further research and experimentation.

Figures 27, 31-39 illustrate some of the forms of illumination and reflectorization that have thus far been used.

Section 328.—Direction of Flow

Whenever loading islands are established in roadway areas, the local traffic authority shall specify, in each case, whether vehicles may pass on both sides of the island or are restricted to pass only on the right. The rule at each island, or in each locality, should be determined after careful analysis, taking into account width of roadway, volume of motor traffic, and volume and character of transit services. A uniform rule, however, along any one street or in one area, where conditions are substantially similar, will be more readily understood and observed.

The requirement that automobiles and trucks shall pass to the right of the loading island may virtually eliminate one traffic lane. However, on streets where parking is permitted the restrictive effect may be minimized by adoption and enforcement of the provision in Act V of the Uniform Vehicle Code (sec. 112) which prohibits parking alongside the islands and for proper distances beyond their ends. In locations where the traffic of transit vehicles stopping alongside loading islands is light and other traffic is fairly heavy, it is usually desirable to permit the general traffic to pass on either side of the island. Allowing other than transit vehicles to pass to the left of the islands, however, may seriously delay streetcars and busses in reaching the islands, with consequent loss of time to passengers and derangement of transit schedules.

Section 329.—Signs

Standard signs indicating the permitted directions of flow shall be placed at the approach end of every loading island that is in the line of traffic flow. When vehicles are required to pass to the right of the island a regulatory Keep Right sign as provided in section 42 shall be used. When passing is permitted on either side the Double Arrow warning sign as provided in section 86 shall be used.

Such signs shall be adequately reflectorized or illuminated. They should normally be mounted at a height of 2½ feet above the pavement to the lowest point of the sign. A duplicate sign, placed with its lower edge at least 7 feet above the pavement, is recommended as a means of giving advance information to approaching traffic.

Standard parking prohibition signs (sec. 47) shall be placed along the curb of the sidewalk adjacent to all loading islands to prohibit parking opposite the entire length of the island and for such distances beyond the ends thereof as are necessary to expedite the flow of traffic (see Act V of the Uniform Vehicle Code, sec. 112).

Section 330.—Markings

The approach-end treatment of a loading island shall include pavement markings as provided in section 139.

The ends of all loading islands toward approaching traffic shall be marked in accordance with section 151. The latter applies particularly to buffers and lighting standards. Markings are also very effective when placed on the curbs of islands in or adjacent to the line of approaching vehicular traffic (sec. 153). If curb or pavement markings are used in other nearby locations to indicate parking prohibitions (sec. 149), such indications should also be used opposite loading islands.

The use of a contrasting color, reflectorized paint, or other special treatment is recommended to indicate clearly the presence of the island, in which case additional curb markings are generally unnecessary.

Summary Specifications for Loading Islands

Designation of area.—Platform preferable; other means include fixed posts or mushroom buttons or combinations of these, with or without pavement markings.

Dimensions:

Length.—Sufficient to accommodate adequate number of streetcars or busses.

Width.—Four feet minimum, wider where needed to prevent overcrowding.

End protection.—Use of buffer is mandatory outside of congested business districts, desirable in such districts.

Approach-end treatment.—Adequate to warn of presence of island and indicate proper vehicle path or paths.

Side protection.—Posts, posts and chains, plates, etc., as conditions require.

Illumination.—General illumination of entire area; intensified illumination and reflectorization of buffers or other structures.

Signs.—Standard Keep Right sign or Double Arrow sign as required.

Markings.—Standard approach pavement markings; standard markings on buffer or curbs.

C—REFUGE ISLANDS

Section 331.—Legal Authority

The models of legal authority applicable to loading islands (safety zones) cited in section 316 are equally applicable to refuge islands, and no other legal authority is involved.

Section 332.—Functions

The main function of refuge islands is to provide a place of safety for pedestrians caught within the roadway on cross walks by changing signals or by oncoming traffic at unsignalized intersections. In congested areas they also expedite vehicular traffic by permitting vehicles to proceed without waiting for pedestrians to cross the entire roadway.

Section 333.—Warrants

Where any one or a combination of the following conditions indicate the need, one or more refuge islands shall be installed:

1. High accident frequency.
2. Dense pedestrian traffic.
3. Dense vehicular traffic.
4. High-speed vehicular traffic.
5. Wide roadway.
6. Complex intersection.

Refuge islands are warranted and shall be used in urban areas on exceptionally wide roadways or in large or irregularly shaped intersections where there is a considerable amount of pedestrian traffic and where heavy volumes of vehicular traffic make it difficult and dangerous for pedestrians to cross (figs. 28, 40, 41). No refuge island shall be placed where it will leave less than two lanes available for traffic between it and the adjacent curb or another island. So placing a refuge island as to confine right-turning movements to a single lane, however, may be desirable if there is not a heavy turning movement.

Refuge islands should not be located in roadways carrying fast-moving vehicles unless they can be so placed, usually in the center of



Figure 40.—A raised refuge island with buffer and curb striped for high visibility.



Figure 41.—An elaborate refuge island with special high-visibility treatment. The cross walk is cut through at pavement level, and pedestrians are well protected from both through and turning vehicles.

the roadway between the opposing streams of traffic, as not to create hazards to the vehicles. At any other point on such roadways where there is any considerable pedestrian movement across the roadway pedestrians should be protected by other means, such as a pedestrian-actuated traffic signal or a pedestrian underpass or overpass.

In urban areas, however, where the vehicular traffic is relatively slow-moving, particularly in intersections without traffic signal control, pedestrians in any considerable number should not be required to find their way through more than four lanes of two-way traffic without the refuge of a center island, or through more than three lanes in one direction without an intermediate island. Such islands may also be desirable at signalized intersections to reduce the clearance periods and expedite traffic.

Section 334.—Location

Refuge islands shall normally be centered on the median line of the roadway. On roadways with streetcar tracks, and two or more lanes of moving traffic on each side of them, refuge islands should be provided on each side of the tracks.

The parts of refuge islands used by pedestrians should be in line with the cross walks.

Section 335.—Elements of Design

Refuge islands normally have the same four distinct parts as loading islands: (1) the area intended to be occupied by pedestrians, (2) a physical barrier at the approach end to prevent motor vehicles from entering the pedestrian area, (3) devices at the approach end to warn vehicle operators of the presence of the island and to direct them into a suitable path or paths past it, and (4) illuminating devices adequate to make all parts of the island clearly visible at night.

Section 336.—Designation of Area

Refuge islands are in practice designated by platforms, markings, or mushroom buttons (figs. 28, 40–45). Raised platforms for part of the width of the cross walk are preferable as they afford pedestrians a greater sense of security. Part of the area, however, should be kept at pavement level to facilitate use by baby carriages, wheel chairs, and crippled or aged persons (fig. 42).

Whatever the form of designation, the requirements for end protection and approach-end treatment stated in sections 339 and 340 apply.

Section 337.—Continuous Median Strip

In roadways requiring median islands at each intersection, consideration should be given to the alternative of a continuous median strip between intersections. Such a strip will obviate the expense of buffers and other approach-end protection at each intersection, minimize weaving between intersections, and afford other advantages of a divided highway. Disadvantages are that it will bar vehicles on one side of the street from direct access to alleys, filling stations and other business facilities, and residences on the other side.

Section 338.—Dimensions

Length and width.—Refuge islands shall be at least 4 feet and preferably at least 6 feet wide. The usable length along the roadway, including the part at pavement level for baby carriages,

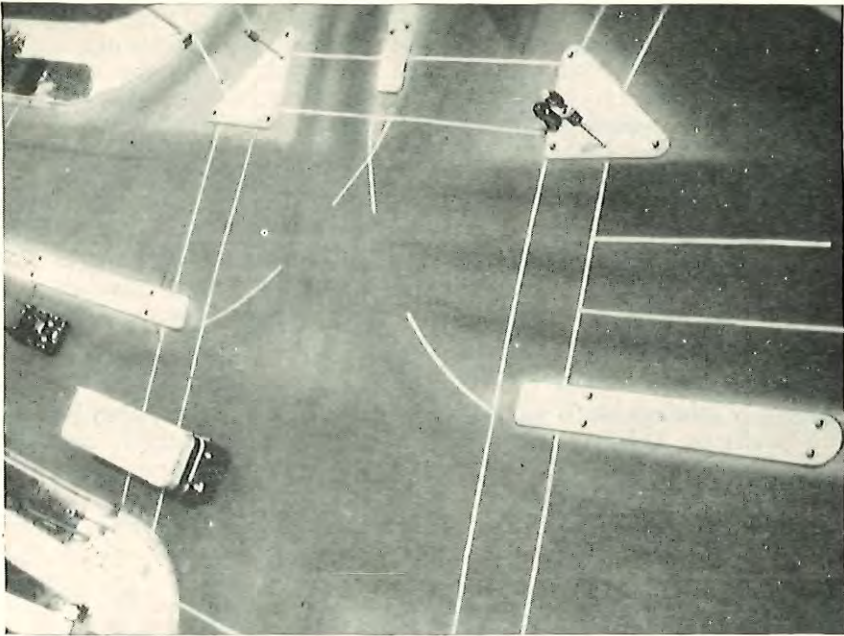


Figure 42.—Combination channelizing and refuge islands with marker lights. The center islands extend into but not entirely across the cross walks.

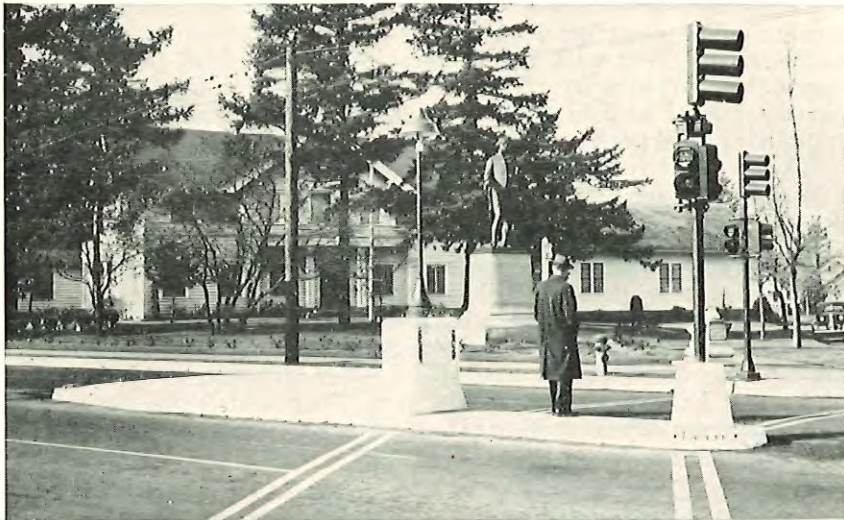


Figure 43.—A combination channelizing and refuge island, with protection from approaching traffic provided by the illuminated buffer and prow at the left. The small buffer at the right provides protection from turning vehicles and serves as a base for the traffic signal.

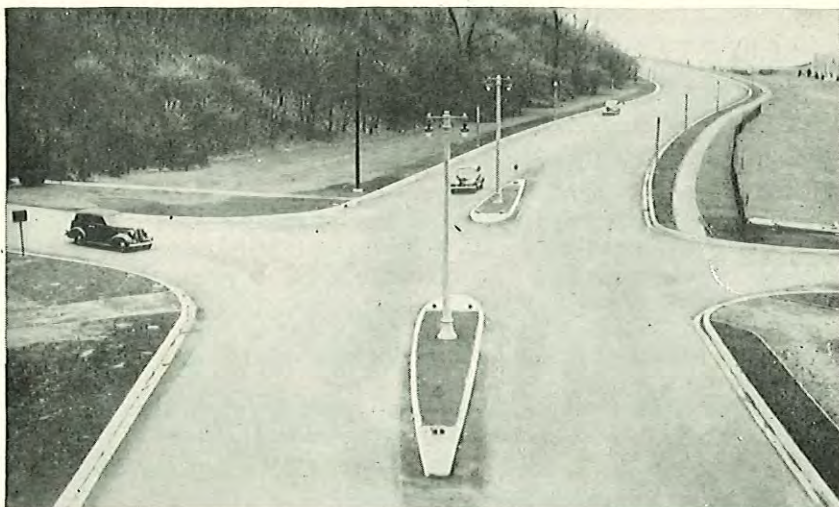


Figure 44.—Combination divisional, channelizing, and refuge islands with desirable tapered shape, curb-level marking lights, and overhead illumination.



Figure 45.—Channelizing islands and pavement markings at a complicated intersection. The raised islands also serve as refuge islands.

wheel chairs, and infirm persons, shall not be less than 5 feet nor less than the width of the cross walk.

Local conditions will determine whether the part of the island at street level is to be adjacent to the intersection, at the center of the cross walk, or elsewhere. In any event the entire area used by pedestrians should be so designed as to be protected against any encroachment by motor vehicles, including those making left turns.

Height.—The platform height of refuge islands shall be from 5 to 7 inches, and in general shall conform to local standards of curb height for sidewalks.

Where additional thickness of roadway pavement surfacing is anticipated due allowance should be made for it.

Section 339.—End Protection

In areas where vehicle speeds are relatively high, a refuge island should have adequate physical protection at the end toward approaching traffic in the form of a buffer to withstand the impact of a colliding vehicle. This buffer may be a concrete block, a series of solid posts or pipes, or other massive structure (figs. 40, 41, 43).

Even in business districts, where speeds may be high after business hours, some form of buffer at the approach end of a refuge island is desirable.

The types of buffers are the same as those described in section 324. Figures 40, 41, 43 show some of the types of end protection that have been used.

Section 340.—Approach-End Treatment

The approach end of a refuge island, whether or not protected by a buffer, shall be carefully designed to provide a maximum degree of warning of the presence of the island and, where necessary, a definite indication of the proper vehicle path or paths to be followed (sec. 325).

Section 341.—Side Protection

When part of the refuge island is kept at pavement level, as recommended in section 336, a mushroom button or more substantial protection should be provided at any corner which might otherwise be encroached upon by turning vehicles.

Section 342.—Illumination and Reflectorization

All refuge islands, including their approach-end treatment, shall be provided with:

1. General illumination of the entire area, including adjacent vehicular-traffic lanes, or as much of the area as is required for safe operation;
2. Intensified illumination and reflectorization to show clearly the outlines of buffers or other structures, collision with which might seriously damage motor vehicles or imperil pedestrians.

Refuge islands shall not be installed unless they can be adequately illuminated. It is desirable to have two independent sources of light in case of failure of one.

Section 343.—Signs

On every refuge island that is in the line of traffic, standard regulatory or warning signs as described in section 329 for loading islands shall be placed at the end toward approaching traffic.

Section 344.—Markings

The approach-end treatment of a refuge island in the line of traffic flow shall include pavement markings as provided in section 139.

The ends of all refuge islands toward approaching traffic shall be marked in accordance with section 151. The latter applies particularly to buffers and lighting standards. Markings are also very

effective when placed on the curbs of islands in or adjacent to the line of approaching vehicle traffic (sec. 153). If curb or pavement markings are used in other nearby locations to indicate parking prohibitions (sec. 149), such indications should also be used opposite refuge islands.

The use of a contrasting color, reflectorized paint, or other special treatment is recommended to indicate clearly the presence of the island, in which case additional curb markings are generally unnecessary.

Summary Specifications for Refuge Islands

Designation of area.—Platform preferable; other means include fixed posts, mushroom buttons, pavement markings, or combinations of these.

Dimensions:

Length.—Cross-walk width, with 5 feet minimum.

Width.—Four feet minimum; preferably 6 feet.

End protection.—Use buffer where speeds are relatively high; desirable in all areas.

Approach-end treatment.—Adequate to warn of presence of island and indicate proper vehicle path or paths.

Side protection.—Mushroom buttons or curb, as needed to prevent vehicle encroachment.

Illumination.—General illumination of entire area; intensified illumination and reflectorization of buffers or other structures.

Signs.—Standard Keep Right sign or Double Arrow sign as required.

Markings.—Standard approach pavement markings; standard markings on buffer or curbs.

D—DIVISIONAL ISLANDS

Section 345.—Legal Authority

Divisional islands are elements of street and highway design and accordingly no special authority is required for their installation.

Section 346.—Functions

Divisional traffic islands are placed longitudinally in roadways to serve any of the following purposes:

1. Along the center line of a roadway of four or more lanes, to separate the streams of traffic flowing in opposite directions (fig. 46).

2. Other than along the center line, in a roadway of six or more lanes, where it is desired to separate the slow-moving local traffic serving the abutting property from the faster through traffic in the center of the roadway.

3. In a roadway of any width, to guide traffic away from a fixed obstruction, such as a bridge support or pedestrian-island buffer (fig. 29).

4. In a roadway at any point where traffic is regularly stopped for toll or inspection purposes.

In some cases they are placed in a roadway of two lanes to prevent vehicles going in the same direction from passing one another at hazardous points, such as narrow bridges, viaducts, underpasses, or dangerous curves. Curved divisional islands are sometimes placed partly around a rotary island to separate the streams of traffic from different entering highways.



Figure 46.—A paved median in a suburban area. The width of the second island is reduced by combined acceleration and deceleration lanes provided for vehicles making left turns to and from the divided street.

Section 347.—Warrants

Any one or a combination of the following conditions may indicate the desirability of installing one or more divisional islands:

1. High accident frequency.
2. Dense vehicular traffic.
3. High-speed vehicular traffic.
4. Wide roadway.
5. Physical obstruction in roadway.

Divisional islands shall be placed in new major thoroughfares of four or more lanes to separate traffic moving in opposite directions. Any streetcar tracks in such new construction shall be within the divisional island.

This discussion is intended to apply primarily to urban areas where intersections are frequent, rather than to open country where continuous median strips are a matter of highway design.

As highway surfaces have been improved and speeds of automobiles have risen, the hazards of passing have vastly increased. While this condition has been met to some extent by widening the roadway to three, four, and even more lanes, the hazard still remains so long as there is a common surface in the center of the highway which is accessible to traffic moving in opposite directions. The only adequate means of eliminating such hazard is the provision of a median strip to separate opposing traffic streams. These strips may be of any width from a narrow curbing to a broad landscaped area.

Median strips, preferably raised, are therefore also recommended for existing roadways where the width permits. Their use to avoid costly end protection and approach-end treatment of refuge islands at a succession of intersections is suggested in section 337.

It is recognized that narrow median strips do not provide adequate protection for left-turning movements and for cross traffic which must wait at the island. Ordinarily this can be accomplished only by widening the island (sec. 350).

Designation of temporary islands by sandbags, stanchions, markings, or other means may be desirable to test a proposed lay-out under actual traffic flow.

Section 348.—Elements of Design

Divisional islands normally have three distinct parts: (1) the area from which motor vehicles are intended to be excluded, (2) an area at the approach end containing devices to warn vehicle operators of the presence of the island and to indicate a suitable path or paths past it, and (3) reflecting or illuminating devices adequate to make the island safe and effective at night.

Unless the island serves also as a refuge island, only sufficient end protection is required to prevent damage to vehicles, to signs or markers, and to the island itself. To afford this the island should contrast in color with the adjacent pavement, and be so designed and located that the proper course of travel is obvious, easy to follow, and unquestionably continuous.

When divisional islands are used to prevent overtaking and passing at hazardous points they should be long enough and so designed as not to introduce a surprise element. A divisional island should not begin on a sharp curve or at the top of or just over a hillcrest.

Section 349.—Designation of Area

In most cases divisional islands are designated by curbs outlining the area, with suitable filler of pavement, turf, or shrubs, depending upon the width, location, and other conditions (figs. 29, 44-48).

Raised curbs are not essential where encroachment on the island is not dangerous to motorists, pedestrians, or property. In this case,



Figure 47.—Separate lanes for left turns are notched into this wide median. The roadway is illuminated and traffic signals control movements at the intersection.

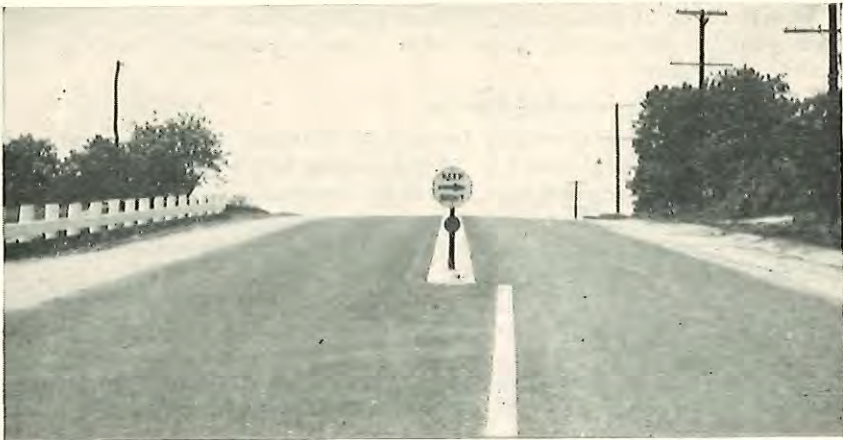


Figure 48.—Introduction of a divisional island in the vicinity of a hill should be well in advance of the crest. Appropriate pavement marking further reduces the hazard.

islands may be designated by pavement markings, stanchions, mushroom buttons, or combinations of these. Sharply contrasting flush sections 15 to 36 inches wide have also been used. Large islands, usually in park areas, may be constructed without curbs, depending instead upon the contrast between the pavement and the island surface or vegetative cover, or upon delineation by guard posts or mounded earth.

At the approach end, divisional islands sometimes are designed to rise gradually from about the pavement level to the height of the curb or mounded center of the normal full-width section. On the other hand, an approach-end treatment, or the island itself, may consist entirely of jiggle bars.

At some locations it may be necessary to place a pedestrian barrier on and along a divisional island to prevent indiscriminate pedestrian crossing of the roadways. The pedestrian barrier usually consists of some form of woven-wire or picket fence at least 3 feet high, located centrally between the island curbs for a full block length, or for a distance of several hundred feet each side of a pedestrian overpass or underpass. Pedestrian barriers so located materially increase the visibility of the divisional island to motorists, and give it a greater over-all effectiveness as a traffic separator.

Section 350.—Dimensions

While the dimensions and shapes of traffic islands cannot be standardized in detail, certain basic principles which are particularly applicable to divisional islands should be observed.

Width.—The width of a divisional island depends on numerous elements, including available right-of-way, traffic-lane requirements, and the extent to which the island is given added protective functions at intersections.

Fixed divisional islands in new construction shall be at least 4 feet wide (fig. 29). This standard, however, should not preclude placing narrower islands in existing roadways where total width is restricted. A single raised and rounded curb has proved effective in some cases.

Where right-of-way is available or obtainable at reasonable cost for a divisional island substantially wider than 4 feet, several points should be taken into account in determining the appropriate width, particularly adjustment to adjoining traffic lanes and protection at cross streets:

1. *Adjustment to adjoining traffic lanes.*—This is a paramount consideration. As a general rule divisional islands should not be placed where they will confine any part of the roadway on either side to less than two free-flowing lanes. The width of these through traffic lanes will be governed by the volume, type, and speed of traffic and by conditions at the locality, somewhat greater widths being necessary for higher speed conditions. For any section of street or highway it is desirable to provide pavements of uniform width. However, variation in width usually is necessary on small-radius curves at intersections and on ramp connections.

In very exceptional cases where a divisional island is desirable even though there is not sufficient space for two lanes of moving traffic on each side of the island, it may be designed for a single lane on the less important side, but this lane should be wide enough to enable other vehicles to proceed slowly past a disabled vehicle, and the restricted width should be limited to sections of relatively short length.

In new construction consideration should be given to the possible need for future narrowing of the divisional island to provide additional traffic lanes.

2. *Protection at cross streets.*—At cross streets it is desirable that divisional islands be of sufficient width to provide protection for vehicles crossing, making left turns, or making U-turns (figs. 46, 49). For cross traffic an island width slightly greater than the length of a vehicle is necessary for protection of the vehicle when it is stopped between the through lanes approximately at right angles to the divided street. Divisional island widths of about 20 feet will protect a passenger car or light truck, but widths of 30 to 50 feet are necessary to protect busses and commercial vehicles crossing approximately at right angles. Greater widths may be necessary, depending upon the minimum turning radii of the vehicles involved, to provide protection for vehicles making left turns to or from the cross road and those making U-turns on the divided streets so that these movements can be made between the proper lanes and with minimum interference with other traffic. An analysis of minimum design for these conditions is to be found in *A Policy on Highway Types (Geometric)* of the American



Figure 49.—At this channelized 'Y' intersection, with irregular-shaped islands, traffic signals regulate the principal crossing movement.

Association of State Highway Officials (pages 24 to 53). As shown therein, island widths of about 20 to 25 feet should be provided for protection of passenger vehicles and 30 to 50 feet for commercial vehicles.

While divisional island widths less than 19 feet and 30 feet for passenger and commercial vehicles, respectively, will not afford full protection for cross traffic, these widths in combination with proper lengths of the opening between ends of the divisional islands may be utilized to afford protection for vehicles making left turns. Consideration also should be given to the effect of the shape of the end of a divisional island, the use of channelizing islands, of skew in the cross-road alignment, and of acceleration and deceleration lanes adjacent to the divisional island.

On a divided through street, left-turning movements at cross streets can be expedited by the provision of median lanes,¹⁰ which are acceleration or deceleration lanes within the divisional island area at the intersection (figs. 46, 47). Any such median lanes should be at least 9 feet wide, with a minimum separation of 4 feet from opposing traffic, and a single median lane will require a minimum width of 13 feet for the divisional island area. Likewise, a median lane on each side will require a divisional area width of at least 22 feet. It should be recognized that such widths will not provide protection for cross-road traffic, as above discussed. Still greater width can be utilized to advantage to place a narrow, low-curbed island at the right of the median lane. At T intersections a center island in the opening may be helpful in directing turning movements.

In designing signals or other protection at intersections of divided streets or highways it should be noted that by definition in Act V of the Uniform Vehicle Code as amended in 1944 (sec. 15) the crossing by another roadway of a divided highway that has a median strip 30 feet or more in width is considered as two separate intersections.

Height.—The character and purpose of a divisional island should determine its height. Those serving also as pedestrian islands should be 5 to 7 inches high. Islands on which there are signals, monuments, or the like, and those intended as a positive bar to vehicular traffic, obviously require curbs of suitable height. Small islands on which there are no objects subject to injury may be low or flush with the pavement to minimize possible damage to vehicles mounting them.

For median strips 20 feet or more in width, except where pedestrian protection is involved, a depressed section without curbs, drained toward the center, is generally advantageous. This will simplify maintenance and facilitate snow removal, providing space for storage of snow and reducing the hazard of ice on the pavement.

Section 351.—Curbs

Different conditions call for several types of curbs bounding traffic islands.

Curbs outlining areas used by pedestrians should be 5 to 7 inches high, with faces nearly vertical. At cross walks, or where there is heavy pedestrian traffic, the lower figure is preferable, due to the danger of pedestrians accidentally stepping off the curb. Such curbs effectively prevent encroachment by most vehicles under ordinary circumstances.

Where pedestrian protection is not involved, islands should be outlined by low, sloping curbs, with the incline not steeper than 45 degrees, so that in emergencies vehicles can mount them without difficulty. Curbs with flat faces are usually found to be more economical in construction than those with rounded faces, and are better adapted for high-visibility treatment. Heights of sloping curbs vary widely depending upon the slope design, but heights of 4 to 8 inches are common.

¹⁰ Sometimes called "shadowing lanes," "pocket lanes," "slots," or other names in local use.

A curb higher than 6 inches should not be used on the end of an island where the width is less than about 6 feet, to prevent damage to the under parts of a vehicle straddling the island.

Barrier curbs intended to confine vehicles to the pavement or to individual lanes should be at least 9 inches high, with a batter of about 1 inch. Such curbs are sometimes favored for narrow divisional islands. It should be recognized, however, that curbs nearly vertical, particularly barrier curbs, reduce the effective width of pavement for vehicle operation, as drivers do not operate close to them. That objection has been partly met in some cases by double curbs, in which a lower step 7 or 8 inches high is surmounted by an additional step set back 5 or 6 inches.

Night visibility of island curbs is important, and construction with white concrete, white stone chips, incorporated reflectors, or reflective facets is recommended.

Section 352.—Approach-End Treatment

Approach-end treatment as here described applies to the beginning of a divisional island, not to each successive part of an island resulting from breaks at or between intersections.

The approach ends of all divisional islands shall be carefully designed to provide, for approaching traffic, a maximum degree of warning of the presence of the island and, where necessary, a definite indication of the proper path or paths to be followed.

Application of this rule, identical with that laid down for loading islands in section 325, will require somewhat different treatment. Unless the island serves also as a pedestrian island there will be no

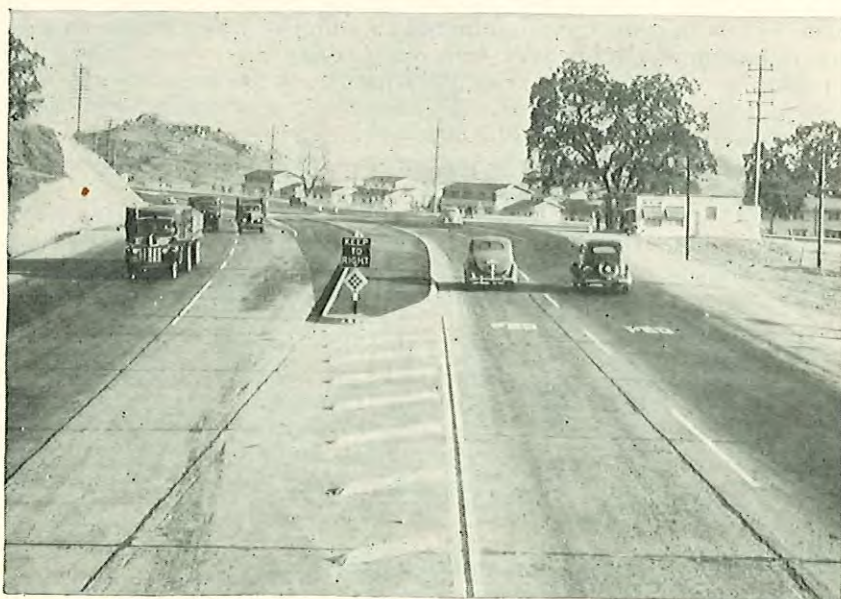


Figure 50.—Approach-end treatment for this median includes jiggle bars, sign, reflector cluster, reflecting curb, and pavement marking. The median is widened for an acceleration lane and for protection of crossing vehicles. The jiggle bars shown here were made of asphaltic mix, placed directly on the concrete and painted white.

need for a buffer or prow to prevent a motor vehicle from mounting the island. On the other hand, particularly at points where vehicle speeds are high, advance warning of the presence of a divisional island and guidance as to the path or paths vehicles should follow is as important as at pedestrian islands, and additional indications are needed at the island proper (figs. 29, 48, 50).

As stated in section 325, the following devices are in use:

1. Pavement markings, with or without mushroom buttons (sec. 355).
2. Signs (sec. 354).
3. Reflecting devices (secs. 152, 156).
4. Flashing yellow beacons (sec. 278).
5. Contrasting pavement colors and textures.
6. Jiggle bars.
7. A vertical element sloping up to the island nose.
8. Various combinations of 1 to 7.

In addition, the approach end of the island may be tapered or otherwise shaped to guide vehicles into the proper roadway or roadways.

In advance of the curbed island nose, pavement markings (sec. 139) or other devices may be placed to outline or fill up the roadway area normally unused by vehicles following a path to clear the island.

Island approach ends should be provided with a form of high-visibility indication to be effective both in daytime and at night. This may be done through the construction of white concrete curbs, by a curb surface coating of light-colored stone chips, paint, or other reflective material, by construction with indented facets to reflect light from headlamps, by incorporation of reflector buttons or other reflective materials, or by other suitable means. Signs located near the ends of the islands and illuminated or suitably reflectorized may be used alone or in conjunction with other treatment. Also, floodlights or other special units for area illumination, or flashing beacons with yellow lenses might be used. To the extent practicable some high-visibility treatment should be continued along the island.

Low-level reflector buttons rather quickly become ineffective, because of dirt, unless frequently cleaned.

At the beginning of a divisional island constituting a median strip the island nose should be offset to the left, as faced by approaching traffic, the right curb of the island forming a diverging taper to deflect traffic toward the right. Where a divisional island is introduced between two lanes of traffic moving in the same direction, similar offsets may be used on each side of the nose to direct traffic into the separate roadways. In both cases the curbed nose should be semicircular, preferably about 3 feet in diameter, the curbs widening beyond to the full width of the island. At cross-road openings in divisional islands the island nose may be made semicircular or of a tapered and rounded shape for left-turning movements, consistent with the island width.

Section 353.—Illumination and Reflectorization

A high intensity of well-directed street lighting is highly desirable at the approach ends of divisional islands to show clearly the locations of the islands and the proper lanes for vehicles to travel. Where facilities for such lighting are not available, the deficiency should be

overcome as fully as possible by such means or combinations as are suggested in section 352.

Section 354.—Signs

A curbed divisional island in the line of traffic flow shall be protected at the approach end by the appropriate reflectorized or illuminated sign or marker. Where the curb-to-curb width is sufficient, 3 feet or more, a regulatory Keep Right sign as described in section 42 shall be used. On narrower islands the reflectorized hazard marker described in section 156 shall be used. To reduce the likelihood of being struck, such signs or markers may be set back about 10 feet from the end of the island.

Section 355.—Markings

The approach end of a divisional island in the line of traffic flow should be designed, signed, and marked to indicate its presence and also to outline the proper vehicle paths. Where necessary the approaches to such islands shall be marked in the manner provided for refuge islands in section 344.

Summary Specifications for Divisional Islands

Designation of area.—Vertical or sloping curbs and filler, mushroom buttons, pavement markings, contrasting materials or island cover, or combinations according to conditions.

Dimensions:

Width.—Four feet minimum in new construction; 20 feet or upward desirable.

Other dimensions.—Depend on conditions.

Approach-end treatment.—Adequate to warn of presence of island and indicate proper vehicle path or paths.

Illumination.—Effective reflectorization or illumination of approach-end treatment.

Signs.—Standard Keep Right sign or reflectorized hazard marker.

Markings.—Where necessary, standard approach pavement markings.

E—CHANNELIZING ISLANDS

Section 356.—Legal Authority

Channelizing islands are elements of street and highway design and accordingly no special authority is required for their installation.

Section 357.—Functions

Channelizing islands are used at intersections to guide motor vehicles into orderly courses. They prevent or reduce undesirable weaving and maneuvering by keeping the vehicles in clearly defined paths. They provide convenient space for necessary signs. They may protect turning vehicles from through traffic moving at higher speeds. They may establish the desired angles for the crossing of vehicle paths. They may permit streams of traffic moving in the same general direction to converge at very small angles, minimizing possible conflicts. Their field of use is discussed in greater detail on pages 51 and 52 of *A Policy on Intersections at Grade*, issued by the American Association of State Highway Officials.

Section 358.—Warrants

Any one or a combination of the following conditions may indicate the desirability of installing one or more islands to channelize or segregate vehicles:

1. High accident frequency.
2. Dense vehicular traffic.
3. High-speed vehicular traffic.
4. Complex intersection.
5. Wide roadway.
6. Difficulty in providing adequate control by standard signs and markings.

Specific warrants cannot be stated. Each location calls for special study. Channelizing islands are warranted and desirable in existing squares, plazas, and other broad expanses of pavement where without them there is a considerable amount of traffic moving in various directions without desirable orderliness. They are warranted at many intersections where traffic signals, involving greater costs of installation and operation, would otherwise be called for under one or more of the signal warrants described in sections 207 and 234. At other intersections where traffic control signals are warranted, the construction of islands may increase the efficiency of the signals.

Proper channelization is desirable at many intersections. A few islands carefully designed and placed to direct the preponderant currents of traffic, however, are far better than a larger number of small islands which create too many channels, confuse vehicle operators, and result in new points of conflict.

Section 359.—Elements of Design

Channelizing islands normally have three distinct parts: (1) the area from which motor vehicles are intended to be excluded, (2) an area at the approach end containing devices to warn vehicle operators of the presence of the island and to indicate a suitable path or paths past it, and (3) illuminating devices adequate to make the island safe and effective at night.

Unless the island serves also as a refuge island, only sufficient end protection is required to prevent damage to vehicles, to signs or markers, and to the island itself. To afford this the island should contrast in color with the surface of the adjacent pavement, and be so designed and located that the proper course of travel is obvious, easy to follow, and unquestionably continuous.

The provision, location, and design of channelizing islands at important grade intersections, particularly irregular intersections, merit careful study. Designation of temporary islands by sandbags, stanchions, markings, or other means may be desirable to test a lay-out under actual traffic flow.

In new construction at intersections, where traffic signals or lights are likely to be utilized as a second stage development, the initial channelization should be patterned to fit the ultimate plan with a minimum of change. It is of considerable assistance to provide conduits or cables initially under the pavements for future use.

Section 360.—Designation of Area

In most cases channelizing islands are designated by curbs outlining the area, with suitable filler of pavement, turf, or shrubs, depending upon the width, location, and other conditions (figs. 30, 44, 45, 49-53).

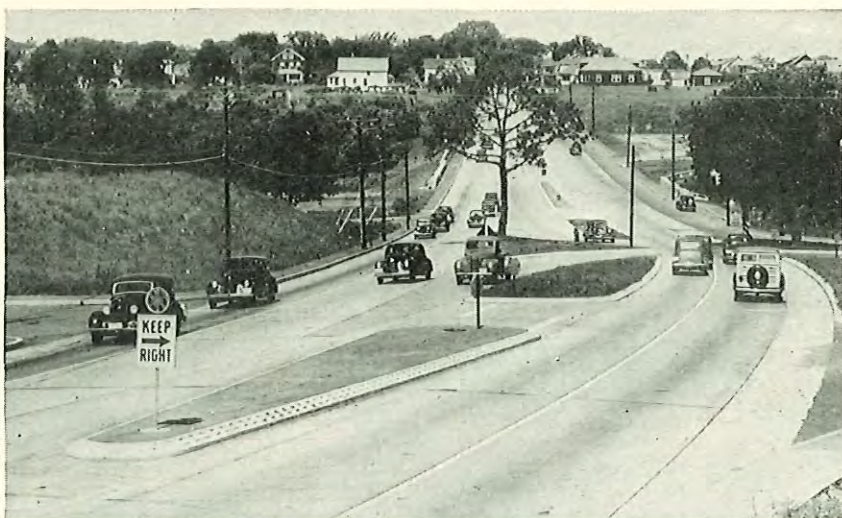


Figure 51.—Separation to permit the addition of central islands was an important factor in the channelization of this intersection. High-visibility curbs were used and an overhead traffic signal regulates the principal crossing movement.



Figure 52.—This channelized T intersection has stop control for crossing movements. The near island is delineated by joggle bars and painted stripes.

Raised curbs are not essential where encroachment on the island is not dangerous to motorists, pedestrians, or property. Islands of this nature may be designated by pavement markings, stanchions, mushroom buttons, or combinations of these (fig. 54). Flush pavement sections 15 to 36 inches wide of sharply contrasting color have also been used. Large channelizing islands, usually in rural areas, may be constructed without curbs, depending instead upon the contrast between the pavement and the island surface or vegetative cover, or upon delineation by guard posts (fig. 55) or mounded earth.

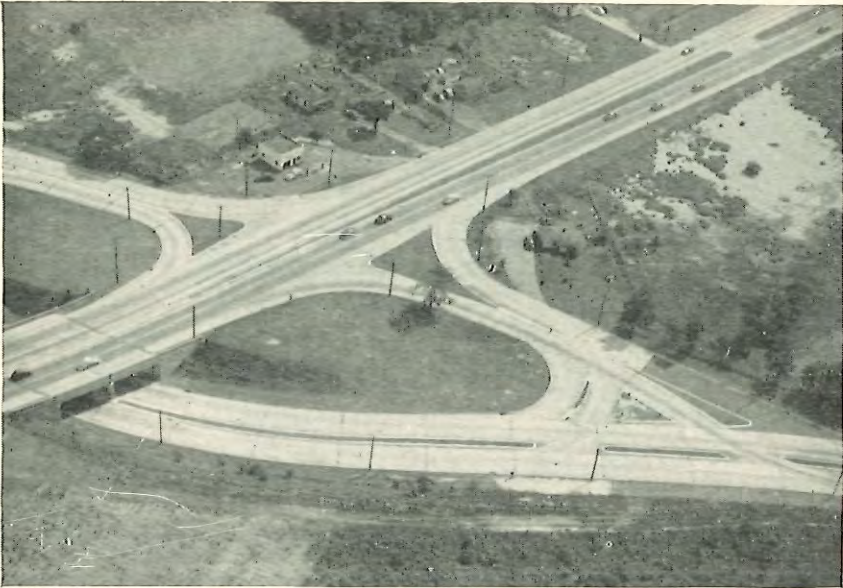


Figure 53.—Channelizing islands of various sizes and shapes are used at the terminals of highway grade separation ramps.

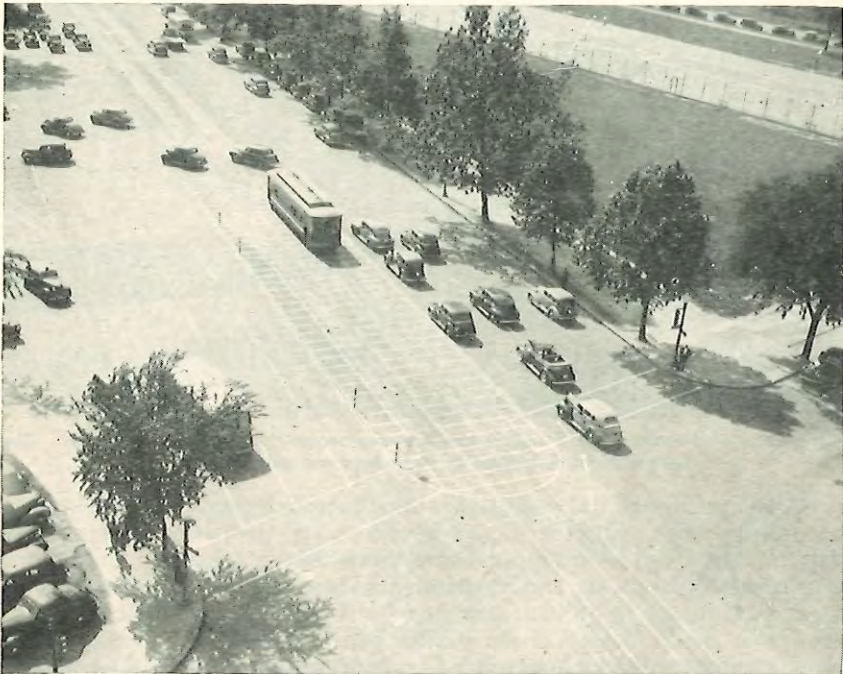


Figure 54.—Painted stripes and stanchions designate this island area from which motor vehicles are excluded.

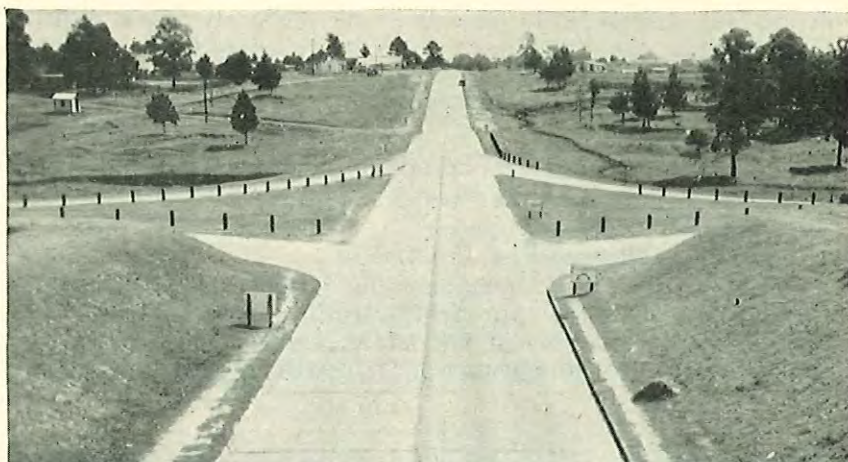


Figure 55.—These ramp terminals are outlined by guard posts along the shoulders. A low, rounded divisional island along the main highway discourages improper left turns.

Section 361.—Dimensions

No fixed rules can be laid down as to dimensions of channelizing islands. They should not be so small as to be inconspicuous to operators of approaching vehicles.

Curbed channelizing islands in new construction shall be at least 4 feet wide. However, this should not preclude placing narrower islands in existing roadways where width is restricted. They should be of proper width to establish correct lane widths. Given in table 3 are pavement widths for separate turning lanes as recommended by the American Association of State Highway Officials in *A Policy on Intersections at Grade* (page 94) and *A Policy on Grade Separations for Intersecting Highways* (page 63).

Table 3.—Pavement widths for separate turning lanes, passenger and truck types of traffic.¹

Radius	Turning speed	One-way one-lane operation				Two-lane operation, either one-way or two-way	
		Does not permit passing of stalled vehicle		Permits passing of stalled vehicle			
		Passenger car	Truck	Passenger car	Truck	Passenger car	Truck
<i>Feet</i>	<i>m. p. h.</i>	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>
50.....	20	14	17	19	28	26	32
75.....	24	13	15	18	25	25	29
100.....	27	13	14	17	24	25	27
150.....	32	13	14	16	22	24	26
200.....	37	13	14	16	22	24	26
300.....	43	12	14	16	21	24	26
400.....	47	12	14	15	20	24	26
500.....	51	12	14	15	20	23	26

¹ As recommended by the American Association of State Highway Officials.

The character and purpose of an island should determine its height. Those serving also as pedestrian islands should be 5 to 7 inches high. Islands on which there are signals, monuments, or the like, and those

intended as a positive bar to vehicular traffic, obviously require curbs of suitable height. Small islands on which there are no objects susceptible to injury may be low or flush with the pavement to minimize possible damage to vehicles mounting them.

Section 362.—Curbs

The specifications and recommendations for curbs bounding divisional islands (sec. 351) are equally applicable for curbs of channelizing islands.

Section 363.—Approach-End Treatment

The approach ends of all channelizing islands shall be carefully designed to provide for approaching traffic a maximum degree of warning of the presence of the island and, where necessary, a definite indication of the proper path or paths to be followed (figs. 30, 50, 51, 56, 57).



Figure 56.—Advantage is taken of curve in this approach-end treatment consisting of a contrasting pavement wedge leading to the curbed island nose. The overhead signs are illuminated.

The detailed information regarding approach-end treatment of divisional islands (sec. 352) is equally applicable to that of channelizing islands. To the extent practicable some high-visibility treatment should be continued around the island.

Low-level reflector buttons rather quickly become ineffective, because of dirt, unless frequently cleaned.

Section 364.—Illumination and Reflectorization

A high intensity of well-directed street lighting is very desirable at the approach end of channelizing islands and at intersections containing such islands, to show clearly their locations and the proper lanes for vehicles to travel. Where facilities for such lighting are not available, the deficiency should be overcome as fully as possible by such means or combinations as are suggested in section 363.

Section 365.—Signs

Channelizing islands in the lines of traffic streams shall be protected at the approach ends by appropriate reflectorized or illuminated signs. As conditions require, a regulatory Keep Right sign

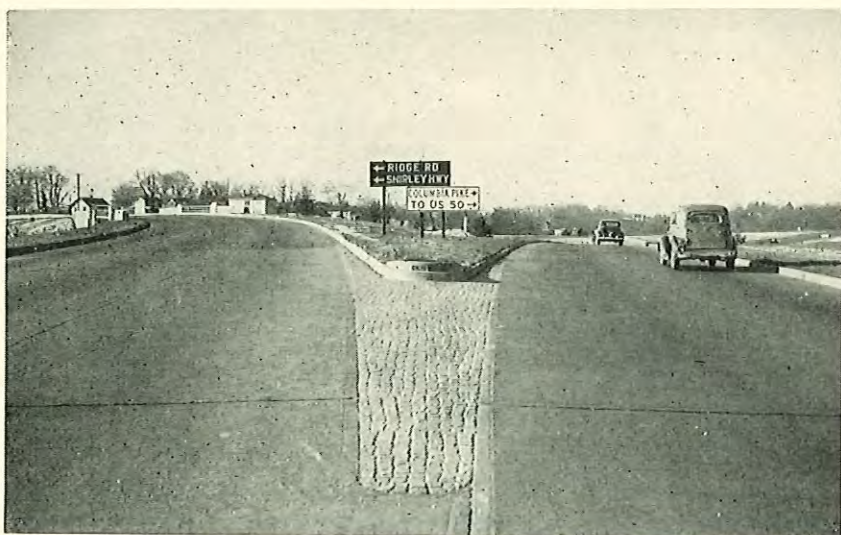


Figure 57.—This approach-end treatment has a slightly raised, roughened tongue in advance of a double curb with inset reflectors. The signs are an experimental installation.

as described in section 42 or a Destination sign as described in section 113 shall be used.

Channelizing islands forming separate turning lanes, i. e., those islands lying to the right or left of pavements for through-traffic streams, likewise should be protected by one or more destination signs at the approach or turn-off end. The assembly on the island may consist of a destination sign with messages for both the through streams and the turning movements or, where the latter have been provided for in advance of the island, only for the through streams. Where site conditions permit, a destination sign should be provided in advance of the turn-off lane formed by the islands, and if necessary the same message repeated in the assembly on the island.

Section 366.—Markings

Channelizing islands in the line of traffic streams, and the approaches to such islands, shall be marked in the manner provided for refuge islands in section 344, not only to indicate the presence of the island but also to outline the proper vehicle paths.

Summary Specifications for Channelizing Islands

Designation of area.—Vertical or sloping curbs and filler; mushroom buttons, pavement markings, contrasting materials or island cover, or combinations according to conditions.

Dimensions:

Width.—Four feet minimum in new construction.

Other dimensions.—Depend on conditions.

Approach-end treatment.—Adequate to warn of presence of island and indicate proper vehicle path or paths.

Illumination.—Effective illumination of approach-end treatment.

Signs.—Standard Keep Right sign or Destination sign.

Markings.—Standard approach pavement markings.

Appendix A

GLOSSARY OF TRAFFIC SIGNAL TERMS

Signals

Traffic Signal—Any power-operated traffic control device, except a sign, by which traffic is warned or is directed to take some specific action.

Traffic Control Signal—A traffic signal which, through its indications, alternately directs traffic to stop and permits it to proceed.

Fixed-Time Signal—A type of traffic control signal which directs traffic to stop and permits it to proceed in accordance with a predetermined time schedule.

Traffic-Actuated Signal—A type of traffic control signal in which the intervals are varied in accordance with the demands of traffic as registered by the actuation of detectors or push buttons.

1. *Semi-traffic-actuated signal*—A type of traffic-actuated signal in which means are provided for traffic actuation on one or more but not all approaches to the intersection.

2. *Full traffic-actuated signal*—A type of traffic-actuated signal in which means are provided for traffic actuation on all approaches to the intersection.

3. *Speed control signal*—A type of traffic control signal in which means are provided for traffic actuation on some or all approaches and which provides Go indications in such a manner that vehicle speeds on one street are limited to a preselected maximum value.

Stop Signal—A flashing red signal having the same function as a Stop sign.

Caution Signal—A flashing yellow signal having the same general function as a warning sign.

Flashing beacon—A section of a standard traffic signal head, or a similar type device, having a yellow or red lens in each face, which is illuminated by rapid intermittent flashes.

Signal Head—An assembly containing one or more signal faces which may be designated accordingly as one-way, two-way, three-way, four-way, or multi-way.

Signal Face—That part of a signal head provided for controlling traffic in a single direction.

Signal Indication—The illumination of a traffic signal lens or of a combination of several lenses at the same time.

Optical Unit—An assembly of reflector, receptacle, redirecting cover glass, and door, with the necessary supporting parts, to be used with a light source for providing a single signal indication.

Redirecting Cover Glass, or Lens—That part of the optical unit which redirects the light coming from the reflector. It is commonly referred to as a lens or roundel.

Signal Support—The physical means whereby a signal head is supported in a particular location.

Signal Installation—All of the equipment and materials involved in the signal control of traffic at one intersection.

Controllers

Controller—A complete electrical mechanism for controlling the operation of traffic control signals, including the timer and all necessary auxiliary apparatus mounted in a cabinet.

Auxiliary Manual Controller—A separate and distinct manual controller attached to an automatic controller by means of which the traffic control signals may be operated by hand when the automatic timer is disconnected.

Fixed-Time Controller—An automatic controller for supervising the operation of traffic control signals in accordance with a predetermined fixed-time cycle and division thereof.

Synchronous Motor Controller—A controller operated by a motor that will maintain a constant speed governed by the frequency of the power supply circuit.

Induction Motor Controller—A controller operated by a motor having variable speed dependent upon the line voltage of the power supply circuit.

Synchronous Supervisory Mechanism—An auxiliary synchronous motor applied to an induction motor-driven traffic controller to cause such controller to keep in step with the constant frequency of the power supply circuit.

Master Controller—A synchronous motor-driven controller, or an induction motor-driven controller provided with a synchronous supervisory mechanism, designed to supervise the operation of all interconnected controllers so as to maintain definite time relationships of all such controllers in the signal system and to operate the remote signal shutdown, flashing indications, total time cycle change, and other features of operation.

Secondary Controller—An automatic controller for operating the traffic control signals at an intersection under the supervision of a master controller.

Local Controller—A controller for operating traffic control signals at an intersection (or two or three proximate intersections) which may be isolated or included in a signal system.

Traffic-Actuated Controller—An electrical mechanism for supervising the operation of traffic signals in accordance with the varying demands of traffic as registered with the controller by detectors or push buttons.

Traffic-Actuated Speed Control—A type of traffic-actuated control designed to provide signal indications that have the effect of limiting the speed of approaching vehicles.

1. **Intersection Speed Control**—A type of traffic-actuated speed control in which speed control features are combined with or are superimposed upon full traffic-actuated control at intersections.

2. **Nonintersection Speed Control**—A type of traffic-actuated speed control designed solely for limiting the speed of approaching vehicles at road locations other than intersections.

Timer—The automatic timing mechanism in a controller, including all dials for adjusting or setting intervals and offsets, switching and flashing mechanism, signal circuit contacts, motors, gears, and camshaft, and also, in the master controller, the total time cycle control and resynchronization or reset mechanisms.

Double Dial Timer—An automatic timer equipped with two timing dials mechanically or electrically interconnected so that it is possible to set up and remotely select any one of three timing programs of all intervals and offset.

Triple Dial Timer—An automatic timer equipped with three timing dials mechanically or electrically interconnected so that it is possible to set up and remotely select any one of three timing programs of all intervals and offset.

Detectors

Detector for Traffic Actuation (general definition)—A device by which vehicles, streetcars, trolley busses, or pedestrians are enabled to register their presence with a traffic-actuated controller.

Pressure-Sensitive Vehicle Detector—A detector installed in the roadway, capable of being actuated by the pressure of a vehicle passing over its surface.

Magnetic Vehicle Detector—A detector installed in or near the roadway, capable of being actuated by the magnetic or electrical disturbance caused by the passage of a vehicle.

Sound-Sensitive Vehicle Detector—A detector installed in or near the roadway, capable of being actuated as a result of sound created by a passing vehicle.

Light-Sensitive Vehicle Detector—A detector installed in or near the roadway, capable of being actuated as a result of a vehicle interrupting a projected light beam.

Streetcar Detector—A detector installed on or near a trolley wire or rail, capable of being operated by the passage of a trolley wheel or shoe.

Nondirectional Detector—A detector capable of being actuated by vehicles proceeding in either direction.

Directional Detector—A detector capable of being actuated only by vehicles proceeding in one direction.

Pedestrian Detector—A detector, usually of the push-button type, installed near the roadway, capable of being operated by hand.

Signal Operation

Time Cycle—The number of seconds required for one complete revolution of the timing dial or complete sequence of signal indications.

Color Sequence—A predetermined consecutive order of appearance of signal color indications during successive intervals within a total time cycle.

Traffic Phase (Traffic Movement)—A part of the time cycle allocated to any traffic movement receiving the right-of-way or to any combination of traffic movements receiving the right-of-way simultaneously during one or more intervals.

Vehicular Phase (Vehicular Movement)—A traffic phase allocated to vehicular traffic.

Pedestrian Phase (Pedestrian Movement)—A traffic phase allocated exclusively to pedestrian traffic.

Interval—Any one of the several divisions of the time cycle during which signal indications do not change.

Clearance Interval—The time of display of the signal indication following the right-of-way interval (generally yellow).

Interval Sequence—The order of appearance of signal indications during successive intervals of a cycle.

Initial Portion—The first part of the green interval which is timed-out or separately controlled by a traffic-actuated controller before the extendible portion of the interval takes effect.

Extendible Portion—The part of the green interval following the initial portion.

Unit Extension—The minimum time, during the extendible portion, for which the right-of-way must remain on any traffic phase following an actuation on that phase, but subject to the extension limit.

Extension Limit—The maximum time for which actuations on any traffic phase may retain the right-of-way after actuation on another traffic phase.

Minimum Period—In semi-traffic-actuated control, the shortest time for which the right-of-way shall be given to the approaches not having detectors.

Manual Operation—The operation of an automatic controller mechanism by means of a hand-operated switch.

Flashing Feature—A relay or other device installed in a controller which when energized from a remote point or by an automatic time switch discontinues normal signal operation and causes the flashing of any predetermined combination of signal lights.

Emergency Feature—A relay or other device installed in a controller which when energized from a remote point discontinues the normal signal operation and displays special signal indications for the movement of high-speed fire apparatus, etc.

System Operation

Signal System—Two or more signal installations operating in coordination.

Simultaneous System—A signal system in which all signals along a given street always give the same indication at the same time.

Alternate System—A signal system in which alternate signals, or groups of signals, give opposite indications to a given street at the same time.

Simple Progressive System—A signal system in which the various signal faces controlling a given street give Go indications in accordance with a time schedule to permit (as nearly as possible) continuous operation of groups of vehicles along the street at a planned rate of speed, which may vary in different parts of the system.

Flexible Progressive System—A signal system in which the intervals at any signal may be independently adjusted to the traffic requirements at the intersection, and in which the Go indications at separate signals may be started independently at the instant that will give the maximum efficiency.

Through Band—The time in seconds elapsed between the passing of the first and the last possible vehicle in a group of vehicles moving in accordance with the designed speed of a progressive signal system.

In-Time Operation—A specified timing relationship of the Go indication between controllers in a system of traffic control signals in accordance with a predetermined timing diagram.

Offset—In a signal system, the interval in seconds between a certain instant arbitrarily used as a time reference base (recurring each cycle) and the start of the Go indication at a given signal in that system.

Single Offset—An adjustment mechanism for setting up the timing arrangement of the start of the Go indication.

Double Offset—An adjustment mechanism providing for the setting up of two timing arrangements of the start of the Go indication, either of which may be selected manually or by means of an electric time switch.

Triple Offset—An adjustment mechanism providing for the setting up of three

timing arrangements of the start of the Go indication, any one of which may be selected manually or by means of an electric time switch.

Offset Dial—A calibrated dial on an automatic timer equipped with adjustment devices by means of which it is possible to set any desired offset of the beginning of the Go signal indication.

Interval Dial—A dial on an automatic timer, calibrated in 1 percent steps, and equipped with adjusting devices by means of which it is possible to divide the total time cycle into the required number of intervals and set up the offset and interlock.

Automatic Reset—A mechanism applied to a traffic signal controller by means of which the timing of the beginning of the Go indication is checked automatically once each total time cycle.

Out-of-Step—That condition of a traffic control signal installation belonging to a signal system when its operation does not possess the intended relationship to the system.

Recoordination—Restoration of the intended interrelationship of operation of signals in a signal system.

Power Failure Feature—A relay mechanism which operates upon restoration of power after a failure, causing traffic control signals to operate as flashing signals or illuminating a power failure indicator until the controller is restored manually to normal in-time operation.

Power Failure Indicator—A pilot lamp mounted on or in the controller cabinet which, when illuminated, indicates that power has failed and that the controller requires manual recoordination.

Remote Cycle Change—A mechanism applied to the timer of the master controller to make possible, by means of manual operation or by means of an automatic time switch, a change in the total time cycle in operation at all local controllers interconnected within a signal system.

Remote Signal Shutdown Relay—A relay installed in a local controller which when energized from a remote point causes signal operation to be discontinued and the signal lights turned off.

Remote Flashing Relay—A relay installed in a local controller which when energized from a remote point causes normal signal operation to be discontinued and specified signal lights to be operated in a flashing manner.

General and Accessory Equipment

Cabinet—A dustproof and weatherproof enclosure for housing the controller and associated equipment.

Panel—An insulated board within the controller cabinet upon which are mounted all fuse receptacles, terminals, relays, hand or electrically operated switches, and other equipment.

Field Terminals—Devices mounted on the panel for connecting all wires entering the controller cabinet.

Signal Contacts—A mechanism arranged to energize or de-energize signal light circuits during a specified signal color interval.

Signal Shut-down Switch—A switch in a traffic signal controller which may be operated by hand to discontinue the operation of traffic control signals.

Radio Interference Eliminator—A combination of choke coils and/or condensers applied to signal light circuits to suppress or minimize interference with radio reception.

Automatic Clock Switch—A device for automatic control of the operation of traffic control signals in any manner prescribed by a predetermined time schedule.

Relay Jack—A clip or receptacles generally installed on the panel into which the prongs of a jack mounted relay may be fitted.

Jack Mounted Relay—A relay equipped with a prong sub-base which may be removed or replaced without disturbing any wiring.

Appendix B

SPECIFICATIONS FOR MATERIALS AND MANUFACTURE

Previous editions of this manual, with the exception of the War Emergency Edition of 1942, have included detailed specifications for sign materials and fabrication, for pavement-marking paint, and for colors of traffic signal lenses. Carefully drawn specifications are essential in the purchase or manufacture of traffic control devices. On the other hand, the continuous improvement that is being made in materials and in manufacturing techniques makes it important that specifications should be flexible. The very best specification as of 1948 might be out of date within the year, due to some new advance in chemistry, optics, or electronics. Also, there are still many shortages in production, and choices of materials may well depend more on availability than on complete adaptability. Specifications, therefore, should be under constant review if maximum service and economy are to be attained. The possibilities for improvement are recognized in some *performance* specifications, which permit the supplier to use his own choice of materials to achieve the specified results.

For many items it is not necessary for the purchaser to prepare elaborate specifications, or to maintain facilities for the testing of materials furnished. In some cases it will be sufficient to cite an existing standard, requiring only that the product conform to that standard. Such a standard might be, for example, a certain specification of the American Society for Testing Materials. In other cases, a leading commercial brand may be accepted as standard, and the call for bids may require quotations on that product "or equal." Commercial testing laboratories and some State highway department laboratories can be called upon to determine whether the product offered meets the specifications. Thus the small as well as the large purchaser can protect himself against the acceptance of substandard, uneconomical, and inefficient traffic control devices, or unsuitable materials for their fabrication.

Certain specifications, such as those for signal wiring or unfinished sign plates, are intended primarily to assure the user that the product he is obtaining will give him satisfactory service for his money. Other specifications, such as those for reflector buttons, traffic signal lenses, or sign enamel, have the added objective of guaranteeing that traffic control devices will be in accord with the design standards required for uniformity in appearance and function, and for efficient performance.

The following suggestions, offered only as a guide to the adoption or formulation of specifications, are intended for the benefit both of purchasers and of those who process materials. Where specifications are cited herein they are presumed to be good, though not necessarily above improvement. In several instances, Federal Specifications¹ are referred to. Other specifications proposed or approved by agencies of national reputation should be accepted as standard until changed by the same or other equally authoritative sponsors. Where typical specifications are not cited an attempt is made to suggest the more important elements that should be considered.

SIGNS

The 1935 edition of this manual included, as an appendix, detailed specifications for the fabrication of signs in various materials and finishes. In many respects these specifications are still valid, though those covering cast-iron signs, for example, have little or no present application. On the other hand, certain new sign materials like sheet aluminum, reflecting coatings, and even reflector buttons, are not mentioned.

¹ Published by the Treasury Department, Bureau of Federal Supply, and available by purchase (generally 5 cents each) from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Wartime shortages as well as war-stimulated technical advances have resulted in changes in the basic materials for sign manufacture. Various types of fiber board, waterproof (resin-bonded) plywood, laminated plastics, and other plastic products, have been found to give satisfactory service under suitable conditions. Some of these substitutes, it may be assumed, have come to stay. The choice between different available materials depends on cost, appearance, and durability. Excessive cost for "permanence" is not justified where damage by violence (accident or vandalism) may require frequent replacement. On the other hand, a low first cost may be poor economy. Where signs are to be quite temporary, however, as for an emergency detour, it may suffice to print them on a water-resistant cardboard.

Metal Signs

For metal sign plates, sheet iron or steel is commonly used, though sheet aluminum has offered some competition in recent years. Sheet steel should be at least 18 gage thickness, U. S. Standard. For plates 24 inches or larger in any dimension, 16 gage metal is preferable for greater strength. Aluminum should be 0.064 to 0.091 inch in thickness.

For unembossed sign plates, having no stiffening bead around the edge, a somewhat heavier gage is desirable.

For steel sign plates, ordinary commercial flat black sheets are satisfactory. If galvanized plates are desired, they may be required to conform to the American Society for Testing Materials Standard Specifications A 93-46, Class D, ordinary coated sheets for general utility, or to Federal Specification QQ-I-716, for galvanized steel sheets, Class D1 or D2.

Aluminum sheet comes in various grades of hardness. A hard temper is desirable, but if the plate is to be embossed it should not be so hard as to crack or tear. Fully soft annealed sheet should be avoided in any case. Aluminum sheet should conform to the American Society for Testing Materials Standard Specifications B 209-46T, Alloy A2 or M1 (2S and 3S, respectively, of the Aluminum Company of America), or to Federal Specification QQ-A-561a or QQ-A-359a, for aluminum plate and sheet.

In embossed signs the details of the design should be raised from the background of the design not less than 0.100 inch nor more than 0.125 inch. The finished embossing should conform to the lines of the working drawings and should be clear and even in outline and free from cracks and tears. The entire sign should be free from twist or buckle, and the background should be substantially a plane surface.

A suitable alloy for cast aluminum signs is covered by the American Society for Testing Materials Standard Specifications B 26-46T, Alloys S1 and S2. Alloy 43, Aluminum Company of America, may also be specified.

A very important step in the fabrication of metal signs is the preparation of the surface before painting, to protect it from corrosion and to improve the adherence of the paint. Hot-dip phosphate treatments are known to give excellent results in enhancing the protective value of paints, on both plain and galvanized steel surfaces,² and certain cold-dip chromate and phosphate treatments have also proved satisfactory. Treatments of both types are available under several proprietary names.

An aluminum surface should be treated with a dilute aqueous solution of phosphoric acid (generally a proprietary process) or with a suitable alkaline cleaner followed by a hot water rinse or treatment in dilute acid. It should then be given a coat of zinc chromate primer. A lead primer should never be used on aluminum.

Painted metal signs should have a priming coat and at least one additional coat on the back and two additional coats on the face. A good grade of baking enamel should be used, having a low-gloss finish to avoid glaring reflections.

Wooden Signs

Wooden signs, other than plywood, should be of yellow poplar, redwood, white pine, yellow pine, fir, or cypress, kiln dried, grading one face clear, other side free from loose knots, large pitch pockets, or other harmful defect. They should have tongue-and-groove joints parallel with the grain of the wood and running in the longer dimension of the finished sign. The glue must be of a waterproof type. Signs should be reinforced with two battens securely fastened to each separate

² *Surface Treatment of Steel Prior to Painting*; Report BMS44, National Bureau of Standards, April 8, 1940, U. S. Government Printing Office.

member of the sign. Sign boards and battens should be of 1-inch stock, surfaced on all sides, and the face of the finished board must be a smooth plane surface.

Plywood must be of the waterproof resin-bonded type. Three-ply fir plywood, Exterior grade, Douglas Fir Plywood Association, is adequate for most standard signs, but a greater thickness should be used for large panels.

For wooden signs a standard exterior linseed oil paint should be used rather than a more brittle enamel. Federal Specifications TT-P-40 and TT-P-101a, for white paint, and TT-P-53 for yellow paint are applicable.

Porcelain Enamel Signs

Vitrified or porcelain enamel signs have high durability if not damaged by accident, but they must be protected against cracking. Bolt holes should be grommeted to prevent chipping. Model specifications for porcelain enamel signs may be obtained on application to the Porcelain Enamel Institute, 1010 Vermont Avenue, N.W., Washington 5, D. C.

Reflecting Elements

The efficiency of reflecting elements depends on their optical characteristics and on their durability under weathering. The brilliance of a reflector button or a reflecting coating cannot be measured as a single value. The intensity of the light reflected from a spot source varies with:

1. The divergence angle, i. e., the angle between the incident light and the light reflected to the observer. A reflector button or a reflecting coating (except the embossed mirror type) is designed to reflect the incident light in a concentrated or focused beam directly back toward its source. Actually there must be enough divergence in the reflected beam to reach the eyes of a driver in his usual position above the headlamps. Any wider spread of the reflected light is largely wasted. For a long-range brilliance the divergence angle may be very small, but if the brilliance is to be maintained at close range, a wider angle is necessary to avoid fade-out. In describing the qualities of a reflecting material, therefore, the brightness at various divergence angles must be specified, or the performance should be required to equal that of a reflector of accepted quality at these angles. Typical tests for reflecting elements require measurement at divergence angles of $\frac{1}{2}$ and 2 degrees (approximately $10\frac{1}{2}$ and 42 inches, respectively, at 100 feet).

2. The entrance angle, i. e., the angle between the ray of incident light and a perpendicular to the front surface of the sign face or reflector. A reflectorized sign or marker is not always in a plane at 90 degrees to approaching traffic. A reflector button or reflecting coating therefore must be capable of functioning without serious loss of brilliancy within a fairly wide variation in entrance angle. Here again the need for a wide angle is greatest at close range, when the passing vehicle is at one side of the reflector, not approaching it head on. Typical reflector tests include measurements at entrance angles of 0, 10, 20, and 30 degrees.

3. The inherent reflecting qualities of the surfaces involved, or the accuracy or consistency with which the optical system can be made to function. The over-all efficiency of different reflectors necessarily varies. Two reflectors of similar optical characteristics may perform at different levels of brilliance, due to differing light losses in refraction and reflection within and at the face of the reflector. Reflecting devices generally tend to become less efficient with weathering.

Standard specifications for reflector buttons and reflecting coatings for traffic control devices have not been agreed upon, primarily because of a lack of accepted data as to just what performance is needed. Excessive brilliance may destroy sign legibility as effectively as insufficient brilliance. For certain signs, like the Stop sign, however, conspicuous visibility may be more important than legibility.

Specifications for delineators and hazard markers are subject to the same requirements as those for reflecting elements in signs, except that high brilliancy need be considered only as a possible source of dazzle, not as a factor in legibility.

A simple technique for measuring the brilliance of reflecting elements by comparison with a calibrated standard is that adopted by the Society of Automotive Engineers as applicable to motor-vehicle reflectors, and published in the *SAE Handbook* as "Reflex Reflectors, SAE Recommended Practice." A somewhat more elaborate method is that developed by Dr. R. Kingslake, of the University

of Rochester, described in the Journal of the Optical Society of America, vol. 28, No. 9, September 1938. This has been used in a number of laboratories as a standard test for sign reflectors.

Complete specifications for reflector buttons should cover materials, dimensions, type of mounting and fittings, lenses and reflectors, optical performance, and durability. Tests for durability usually include intensive corrosion and weathering exposure, such as salt spray and sudden changes in temperature, designed to reveal any weakness in the seal protecting the reflecting surfaces. In the case of reflector hazard markers, color must also be specified.

For reflecting coatings, in addition to requirements as to optical characteristics, it is necessary to specify color, weather resistance (including ultraviolet light exposure for paints and plastic materials), and method of attachment to the sign plate.

Reflector buttons and reflecting coatings produced by well established manufacturers, however, can usually be purchased without detailed specifications, as their performance can be guaranteed by the maker. A practical approach will involve a test comparison of several products as a basis for selection before purchase.

Sign Colors

Where yellow is specified for signs, it should conform with the color cards for "highway yellow," available from the Public Roads Administration. This is a chrome yellow, normally produced as a lead chromate pigment. There are no similar standards available for the red and green required on parking signs. Many red pigments have a tendency to fade, but a strong, clear red of good durability can be obtained with a toluidine red pigment. Green should be a bright chrome green, normally a combination of lead chromate and insoluble Prussian blue.

Sign Posts and Mounting

Posts for sign mounting may be of any material that will give good and economical service, and local availability is usually an important consideration. Various designs of steel sections or pipe, installed by driving into the ground, have been commonly used. For channel sections weights of from 1½ to 2½ pounds per lineal foot have been specified, depending on the strength required. The usual commercial grades of bar steel may be assumed to be satisfactory for sign posts, but if a steel specification is desired, Federal Specification QQ-B-71a for reinforcement bars is suggested. Pipe posts should be anchored to prevent turning. Steel posts should be galvanized or well painted to prevent rusting.

Wooden posts, treated with a suitable preservative, have given good service. They should be at least 4 inches square in cross section, depending on the size of the sign to be mounted. Concrete posts, with suitable reinforcing steel, are also good, though less adaptable to varied bolt-hole requirements.

All posts should be of sufficient length to set rigidly in the ground, but they should not generally extend above the signs or sign assemblies mounted upon them.

The variety of sign sizes and lay-outs makes it impracticable to maintain a uniform spacing of bolt holes in the sign plates. Standard posts, to accommodate flexibly any sign or assembly of signs, should accordingly have holes punched or drilled on 1-inch centers throughout the upper portion of their length. Holes near the ground level should be avoided, as they weaken the post where maximum strength is required. Wooden posts can, of course, be drilled in the field to fit any sign. Concrete posts cannot practicably be made with a hole spacing of much less than 3 inches, center to center. Posts with holes on 6-inch centers will fit all warning signs illustrated in this manual, and those with holes on 3-inch centers will also fit most of the regulatory signs. For nearly all guide signs, other than the shield route markers, the 1-inch spacing is necessary.

Signs should be mounted with rust-resistant bolts and washers, to prevent discoloration of the sign face and to permit easy removal. Fiber washers of a color matching the sign background are recommended for use under the bolt head. Experience may indicate a need in some areas for special vandal-resisting bolt fittings.

PAVEMENT MARKINGS

Much research has been devoted to the development of materials for pavement markings, and particularly to the improvement of "traffic paint."

Paint

Pavement-marking paint must not only be capable of taking the hardest kind of wear under severe exposure to weather, but it must also dry very rapidly after application. As a typical specification, there may be cited Federal Specification TT-P-115, for white and yellow traffic paint. This gives wide latitude in composition, but requires that quality, as determined by abrasion and accelerated weathering tests, shall at least equal that of a "comparison paint" of a prescribed formula. Some highway departments have been purchasing their paint even more definitely on a performance basis. Bidders are required to submit samples, which are applied in test stripes on a pavement. The award is made after comparing durability, appearance, and price. The Ohio State Department of Highways has developed an excellent specification of this type.

For yellow pavement markings the specified color is that shown in the color cards for "highway yellow," available from the Public Roads Administration.

Reflectorized Markings

The most common type of reflectorized pavement marking is that in which small glass spheres are incorporated in a painted surface, either by scattering them into the wet paint immediately after application, or by mixing them in the paint before application. Glass-beaded paints are available under several trade names, and, to assure satisfactory materials and performance, it is suggested that the choice in purchase be based on performance tests as for paint.

Unit Pavement Markers

No standard specifications, other than the general requirements of section 122 of this manual, are available for the types of markings made up of small, flat or slightly rounded units on the pavement surface. Particular attention should be given to the adequacy of the means used for anchoring or cementing these units to the pavement, and to their durability under traffic.

TRAFFIC SIGNALS

Traffic signal specifications must cover the signal head units, the controllers, the detectors (if traffic-actuated), and the accessory wiring and fittings.

Signal Heads

The standard specification for signal heads is that in Technical Report No. 1 of the Institute of Traffic Engineers, *Adjustable Face Traffic Control Signal Head Standards*, approved as an American Standard (D 10.1-1942) by the American Standards Association.³ This covers the design and material for housings, lenses, reflectors, and lights, giving particular emphasis to color, intensity, and candle-power distribution of the signal lights.

Signal Controllers

Specifications for signal controllers must be drawn to cover the requirements of any particular installation or system of signals. It is generally desirable to provide for greater flexibility than is regarded as immediately necessary, both to permit subsequent adjustment of changing conditions, and to assure a factor of safety in the form of reserve circuits. For fixed-time signal controllers the authoritative specification is that in Technical Report No. 2 of the Institute of Traffic Engineers, *Pre-timed, Fixed Cycle Traffic Signal Controllers*, approved as an American Standard (D 11.1-1943) by the American Standards Association.³

Traffic-actuated signal controllers must meet many of the specifications of the standard cited in the preceding paragraph, but must in addition be designed to receive impulses from one or more detectors, and to respond to those impulses only in accordance with a prearranged system of priorities. Since many installations of traffic-actuated equipment must be especially designed to deal with irregular traffic conditions, the requirements for the controllers will vary accordingly. The advice of manufacturers will be valuable in planning a given installation, and in drawing specifications therefor. The Institute of Traffic Engineers has in preparation a standard specification for traffic-actuated signal controllers, similar to its specification for fixed-time controllers.

Detectors are to be regarded as a feature of the signal controller, and specifications should be drawn accordingly.

³ Obtainable from the Institute of Traffic Engineers, Strathcona Hall, New Haven 11, Connecticut, or from the American Standards Association, 70 East 45th Street, New York 17, N. Y. (price, 25 cents).

Wiring and Fittings

Cables and wiring of traffic signals must, of course, depend on the type of installation (e. g., whether underground or overhead), the number of circuits required, and the electrical load to be carried. Suggestions are to be found in section 184 of this manual, and in the *Traffic Engineering Handbook*, published jointly by the Institute of Traffic Engineers and the National Conservation Bureau, but any specification must be based on sound electrical engineering practice. The signal manufacturer, the electric utility company, or the city electrician can be consulted for recommendations. Recent developments in insulation have simplified the installation of underground wiring. Specifications for numerous types of cables, to meet varied requirements, have been approved by the American Society for Testing Materials, and there are several applicable Federal Specifications.

Although a color coding of the conductors in all cables is recommended, there is as yet no generally accepted code for signal circuits. A suggested code may be found in the *Traffic Engineering Handbook*.

Conduits and fittings, as needed, should be of standard approved designs. Recommendations of the signal manufacturer will be a useful guide in their selection. Practical suggestions are also to be found in the *Traffic Engineering Handbook*.

	Section
Channelizing islands—Continued	
Pavement approach markings	139
Reflectorization	364
Signs	365
Specification, summary	Page 203
Traffic signals on	175
Warrants	358
Width	361
Cleaning:	
Signals	197
Signs	22
Clearance interval:	
All-red	194
Fixed-time signals	220
Length	194, 220, 266
Traffic-actuated signals	255, 256
Use after red indication, disapproved	194
Use as pedestrian walk period disapproved	194
Clearance, overhead, restricted:	
Low Clearance sign	80
Markings	150, 156
Clearance, streetcars, pavement markings	140
Collision diagram	206, 212
Color:	
Delineators	157
Hazard markers	156
Islands	313, 324, 330, 344, 348, 359
Markings	123
Signs	8
Guide signs	94
Regulatory signs	27
Warning signs	57
Traffic signals	166, 167
Color cards, highway yellow	8, 123
Color code, traffic signal cables	184
Color specifications:	
Pavement markings	123
Signs	8, Page 212
Traffic signals	166, Page 213
Combination Junction sign	101
Commercial vehicles, effect on signal timing	220, 266
Commercial Vehicles Excluded sign	44
Condition diagram	206
Conduit, signal cables	183
Confirming Marker	95, 98, 104
Controlled-access highways:	
Center lines	130
Lane markings	133
Selective exclusion signs	44
Controllers, fixed-time signals:	
Coordination	218
Nonsynchronous type	215
Program type	216
Specifications	Page 213
Synchronous type	216
Controllers, flashing signals or beacons	280
Controllers, maintenance of	198
Controllers, traffic-actuated	250-258
Coordinated movement, warrant for fixed-time signal	211
Coordination	
Fixed-time signals	221-227
Traffic-actuated signals	239
Cross On Green Light Only sign	51
Cross On Walk Signal Only sign	51
Cross Only At Cross Walk sign	51
Cross Road sign	64
Cross walk:	
Definition	Page 4
Pavement markings	142, 144
Signs	51, 92
Stop lines at marked cross walks	143
Cross Walk sign	92
Crossbuck, Railroad sign	89
Crossing signs	90
Crossings, pavement markings	90
Curb:	
Channelizing islands	360, 362
Divisional islands	349, 351
Curb markings, object	151, 153
Color and design	123, 153
Loading islands	330
Refuge islands	334

	Section
Curb markings, parking prohibition----	149
Color-----	123
Loading islands, adjacent to-----	330
Refuge islands, adjacent to-----	344
Curve signs-----	60, 62
Cycle, traffic signal, length-----	189

D

Dashed lines. (See Broken lines.)	
Deceleration lanes at divisional islands	350
Deer Crossing sign	90
Definitions	Pages 3, 205
Delineators:	
Application	155, 157
Color	123, 157
Definition	Page 5
Design	122, 157
Pavement-width transitions	75, 138
Signs, distinguished from	23
Spacing, horizontal and vertical curves	157
Specifications	Page 211
Winding road	63
Demand signals. (See Traffic-actuated signals.)	
Destination sign	113, 114
Location	114, 305
Warrants	113
Detectors, traffic-actuated signals	243-249,
Installation	259-263
Location	260-263
Types	244-249
Directional and nondirectional	245, 246, 248, 261
Light-sensitive	248, 261
Magnetic, compensated and noncompensated	246, 261
Pressure-sensitive	245, 261
Push-button, pedestrian	249, 262
Sound-sensitive	247, 261
Streetcar	263
Detours	107, 111
Detour marker	111
Road Closed sign with Detour Marker	53
Temporary Route Marker at	107
Dip sign	73
Directional Marker	95, 104-106
With Detour Marker	111
Distance sign	115
Divergence angle, reflecting elements	15,
	Page 211
Divided Highway Ahead sign	76
Divided Highway Ends sign	77
Divisional islands	345-355
Approach-end treatment	352
Color	348
Curbs	351
Definition	Page 5
Design	348-355
Designation of area	349
Dimensions	350
Discontinuous, distinguished from median strips	312
Functions	346
Height	350
Illumination	353
Legal authority	345
Markings	355
Reflectorization	353
Signs on	354
Specifications, summary	Page 197
Warrants	347
Width	350
Do Not Enter sign	43
Double Arrow sign	86
Keep Right sign, alternative to	42
Loading islands, use at	329
Obstructions in roadway, applications	151, 156
Douglas Fir Plywood Association	Page 211
Drawbridge sign	92
Drawbridge signals	290-294
Drawings, signs	6, 11

E	Section
Elongated letters, pavement markings	148
Embossed signs, specifications	Page 210
End (35) Mile Speed sign	33, 36
End No Passing Zone sign	40
End protection:	
Channelizing islands	359
Divisional islands	348
Loading islands	324
Refuge islands	339
Enforcement, regulatory signs	2, 25
Entrance angle, reflecting elements	Page 211
Exclusion signs	44
Extendible portion of Go interval	266
Extension Limit, signal interval	251-
	255, 266
Adjustment	266
Limits of adjustability	251-255
Extension period of signal interval	250, 251

F	
Factory Entrance sign	92
Federal-aid Highway Act of 1944	Page 1
Federal specifications	Pages 209-213
Federal yellow. (See Highway yellow.)	
Fixed-time traffic signals:	
Advantages	201, 204
Characteristics	201
Coordination of	221-227
Definition	Page 5, 205
Efficiency of	227
Flashing operation	208, 232
Master controller	225, 226
Selection of control mechanism	214
Warrants	159, 207-213
Flashing beacon (see also Flashing signal):	
Colors	278, 281
Controls	280
Definition	278
Design	281
Islands, use on	325, 352
Location	282
Meaning	167, 279
Obscured traffic signal, use in advance of	175
Operation	283
Rate of flashing	232
Red, with stop sign	14
Warrants	279
Yellow, with warning sign	14
Flashing light signals, railroad crossing. (See Train-approach signals.)	
Flashing operation, when Stop-and-Go operation is not warranted	30, 188
Fixed-time signal	208, 210, 232, 279
Traffic-actuated signal	265
Flashing red. (See Flashing beacon; Flashing signal.)	
Flashing signal:	
Colors	278, 281
Controls	280
Definition	278
Design	281
Meaning	167, 279
Operation	283
Rate of flashing	232
Stop-and-Go operation, substitution for	30,
	188, 208-210, 232, 265, 279
Warrants	279
Flashing Yellow. (See Flashing beacon; Flashing signal.)	
Flexible progressive system	226
Traffic-actuation at critical points	234, 239
Four-way stop	30
Fresh Oil sign	83
Fresh Tar sign	83
Full traffic-actuated signals (see also Traffic-actuated signals):	
Application	238
Controllers	250, 254, 256
Definition	Page 5, 233

Section
Full traffic-actuated signals—Continued
Operation
Time intervals, adjustment of
Volume-density controller
238
266
238

G	
Gates, railroad crossing, automatic	304-
	311
Application	304
Controls	306
Design	307
Installation	309
Location	308
Operation	310
Maintenance	311
Standardization	160
Traffic signals, coordination with	208, 231
Warrants	305
Gates, with traffic signals at draw-bridge	291
Glossary of traffic signal terms	Page 205
Green:	
Parking restriction signs, lettering on	47
Traffic signals, meaning in	167
Green arrow, in traffic signals	167, 168
Guide signs	93-117
Application	93
Classification	3, 93
Color	8, 94
Definition	Page 4
Design	7, 8, 13, 16, 94
Function	3
Text and symbols, individual signs	96,
	97, 99-104, 106-113, 115-117
White lettering on black background	8, 94

H	
Hazard markers:	
Application	155, 156
Color	123, 156
Design	122, 156
Divisional islands, use on	354
Narrow bridges, use at	78, 79
Height:	
Islands	323, 338, 350, 361
Signs	17
Traffic signal faces	176
High Water sign	92
Highway, definition	Page 3
Highway lighting, alternative to traffic signals	212
Highway traffic signal, definition (see also Traffic signals)	Page 5, 158
Highway yellow	8, 123, Page 212
Hill sign	71
Hospital sign	92

I	
Illumination, islands:	
Channelizing islands	364
Divisional islands	353
Loading islands	321, 325, 327
Refuge islands	342
Illumination, signs (see also Reflection)	13, 14
Color	14
Guide signs	94
Means of illumination	14
Stop sign	29
Traffic signals, signs on	172
Illumination, traffic signals	170
Industrial plants, traffic signals at	209
Information signs	117
Initial portion of signal interval	250-
	252, 254-256, 266
Adjustment of	266
Limits of adjustment	251, 252, 254, 255
Institute of Traffic Engineers	136,
	166, 168, 219, 272, Pages 1, 213, 214
Interruption of continuous traffic, warrant for fixed-time signal	209

	Section		Section
Intersection :		Legibility :	
Control at-----	Page 2	Rounded lettering-----	12
Cross-walk lines-----	144	White letters on black back-	
Definition-----	Page 4	ground-----	8
Divisional island, design at-----	350	Lenses, traffic signal :	
Route markings-----	95-106, 113, 114	Arrangement in signal face-----	166
Stop lines-----	143	Color-----	165, 166
Warning signs-----	64-67	Design-----	168, 169, 171
Intervals, traffic signal :		Number in signal face-----	165
Adjustment to traffic require-		Lettering :	
ments-----	192, 219, 220, 266	Elongated, for pavement mark-	
Fixed-time signals-----	219, 220	ing-----	148
Pedestrian signals-----	276	Signal lenses, disapproved on-----	169
Sequence-----	191, 267	Traffic signs-----	12
Traffic-actuated signals-----	266, 267	Letters, unit, for pavement marking-----	122
Islands (see also Channelizing Is-		Lighting, highway, alternative to traf-	
lands : Divisional islands ; Loading		fic signals-----	212
islands ; Refuge islands)-----	312-366	Light-sensitive detector-----	248, 261
Approach-end treatment-----	321,	Limit Line. (See Stop line.)-----	
325, 327, 329, 330, 340, 352,	363	Load Limit (10) Tons sign-----	54
Classification-----	314	Loading islands-----	316-330
Color-----	313	Access to-----	320
Definition-----	Page 5	Approach-end treatment-----	321,
Double Arrow sign at-----	86	325, 327, 329, 330	
End protection-----	324, 339, 359	Color-----	324, 330
Engineering requirements-----	313	Cross-walk lines at-----	144
Function-----	312	Definition-----	Page 5
Keep Right sign at-----	42	Design-----	321
Maintenance-----	313	Designation of area-----	322
Signs on-----	17, 42, 86	Dimensions-----	323
Standardization-----	315	Direction of traffic flow-----	328
Traffic signals, as alternative to-----	212,	End protection-----	324
	358	Functions-----	317
Traffic signals on-----	182	Height-----	323
		Illumination-----	321, 327
J		Legal authority-----	316
Jiggle bars :		Location-----	319
Definition-----	Page 5	Markings-----	330
Islands, use in design of-----	325, 349, 352	Midblock location-----	320
Joint Committee on Grade Crossing		Posts, end and side protection-----	322,
Protection (see also Association of			324, 326
American Railroads)-----	89	Reflectorization-----	327, 330
Junction sign-----	99-101	Side protection-----	321, 326
Cross Road sign not to be used		Signs at-----	329
with-----	64	Specifications, summary-----	Page 183
		Warrants-----	318
K		Width-----	323
Keep Right Except To Pass sign-----	41	Low Clearance sign-----	80
Keep Right sign-----	42	Lubrication, signal controllers-----	198
Channelizing island-----	365		
Divisional island-----	354	M	
Loading island-----	329	Magnetic detectors-----	246, 261
Obstructions-----	151, 156	Maintenance :	
		Islands-----	313
L		Markings-----	127
Lamps, traffic signal-----	170, 196	Signs-----	22
Lane-direction traffic signals-----	284-289	Traffic signals-----	195-200
Application-----	284	Major route, definition-----	24
Control mechanism-----	286	Markings-----	118-157
Definition-----	284	Color-----	123
Design-----	287	Curb markings-----	123, 153
Location-----	288	Functions-----	118
Operation-----	289	Islands, use on-----	330,
Warrants-----	285		336, 344, 355, 366
Lane lines-----	131-133	Legal authority-----	119
Application-----	131	Limitations-----	118
Definition-----	Page 4	Maintenance-----	127
Design-----	123-125, 132, 133	Materials-----	122
Warrants-----	131	Object markings-----	150-154
Lane marking, as alternative to traf-		Pavement markings-----	118-148
fic signals-----	212	Standardization-----	120
Lane widths, at channelizing islands-----	361	Types-----	121
Large Arrow sign-----	68	Manual control of traffic signals-----	228, 258
Roadway obstructions-----	156	Mast-arm suspension, traffic signals-----	182
Turn signs, supplementing-----	59	Master controller, fixed-time signals-----	218,
Warrants-----	68		225, 226
Left turns, warrant for traffic signal-----	209	Master timer, supervisory background	
Legal authority :		cycle-----	239
Channelizing islands-----	356	Materials, sign-----	20, Pages 209-212
Divisional islands-----	345	Maximum period, traffic-actuated sig-	
Loading islands-----	316	nals-----	250
Markings-----	119	Adjustment of-----	266
Refuge islands-----	331	Limits of adjustment-----	251, 252, 254-256
Signs-----	2	Median lanes, in divisional islands-----	350
Traffic signals-----	161		

	Section
Median strip, as divisional island.....	347
Continuous, as alternative to refuge islands.....	337
Divided Highway Ahead sign on.....	76
Men Working sign.....	82
Authority for.....	2
Reflectorization, if used at night.....	13
Messenger wire, for signal cables.....	187
Metal, for signs.....	Page 210
Mileage on destination and distance signs.....	113, 115
Minimum period, semi-traffic-actuated signals.....	250, 251
Model Traffic Ordinance.....	Page 1, 161, 316
Mushroom buttons:	
Hazards.....	122, 150
Islands, use in.....	322, 325, 336, 349, 360

N

Narrow Bridge sign.....	78
Narrow Road sign.....	74
Narrow roadway, one-way control by traffic-actuated signal.....	242
Narrow roadway signs.....	74, 75, 78, 79
National Committee on Uniform Traffic Laws and Ordinances.....	Page 1
National Conference on Street and Highway Safety.....	Page 1
National Conservation Bureau.....	136, 219
Night speed limit.....	32, 34
Night speed sign.....	34
No Dumping Allowed sign.....	55
No Fishing From Bridge sign.....	55
No Hitch Hiking sign.....	55
No Left Turn sign.....	37
No Parking On Pavement sign.....	49
No Parking signs.....	47-49
No Passing sign.....	39
No-passing zones.....	39, 40, 134-136
Barrier lines.....	124, 126
Pavement markings.....	134-136
Signs, supplementary to pavement markings.....	39, 40, 135
Warrants.....	136
No Pedestrian Crossing sign.....	51
No Right Turn sign.....	37
No Stopping On Pavement sign.....	49
No Stopping signs.....	47-49
No Trucks sign.....	44
No Turns sign.....	37
No U Turn sign.....	37
Nonintersection control, traffic-actuated signals.....	235
Nonsynchronous controllers, fixed-time signals.....	215

O

Object markings.....	122, 150-154
Application.....	150
Color.....	123, 151, 153, 154
Curbs.....	153
Design.....	151-154
Reflectorization.....	126
Types.....	121
Obstruction in roadway:	
Double Arrow sign.....	86
Keep Right sign.....	42
Lighting.....	152
Object markings.....	151
Pavement markings.....	139, 151
Reflectorization.....	152
Signals on pedestals in roadway disapproved.....	175
Official traffic control devices, definition.....	Page 4
Ohio State Department of Highways.....	94, Page 213
One-way restricted zone, traffic-actuated signals.....	235, 242, 256, 266
Controller, operation of.....	242
Intervals, timing of.....	266
Limits of adjustment of intervals.....	256

	Section
One Way sign (<i>see also</i> Do Not Enter sign; Two Way Traffic Ahead sign).....	45
Preferable to Turn Prohibition sign where applicable.....	37
Overhead clearance.....	80
Overhead suspension:	
Signals.....	182
Signs.....	17, 37
Oversize signs.....	9
Directional Marker.....	106
Hill sign.....	71
Junction sign.....	100
Route Marker.....	97
Speed signs.....	32, 34-36
Turn Markers.....	103
White lettering on guide signs.....	94

P

Paint:	
Pavement markings.....	122, Page 213
Signs.....	Pages 210, 211
Parking prohibition:	
Curb markings.....	123, 149
Islands, adjacent to.....	329, 330, 344
Signs.....	47-49
Parking regulation, as alternative to traffic signal installation.....	212
Parking restriction signs.....	47, 48
Parking space limits, pavement marking.....	147
Pavement, definition of.....	Page 3
Pavement edge marking.....	137
Pavement Ends sign.....	81
Pavement markings.....	118-148
Approach to obstruction.....	139
Broken lines.....	124
Built-in markings.....	122
Buttons.....	122
Center lines.....	128-130
Colors.....	123
Cross-walk lines.....	144
Design.....	124, 125
Functions and limitations.....	118
Islands, approach-end treatment.....	325, 330, 344, 352, 355, 363
Islands, designation of area.....	322, 336, 349, 360
Lane lines.....	131-133
Legal authority.....	119
Maintenance.....	127
Materials.....	122, Page 213
Mushroom buttons.....	122
No-passing zones.....	134, 136
Obstruction, approach to.....	139
Parking space limits.....	147
Pavement edges.....	137
Pavement-width transitions.....	138
Railroad crossing, approach to.....	146
Reflectorization.....	122, 126
Route directions.....	145
Specifications.....	Pages 212, 213
Standardization.....	120
Stop lines.....	143
Streetcar clearance lines.....	140
Traffic signal installation, as alternative to.....	212
Transverse lines.....	142
Turn markings.....	141
Types.....	121, 124
Unit inserts.....	122
Wet Paint sign.....	55
Word markings.....	148
Pavement Narrows sign.....	75
Pavement-width transitions.....	74-79, 138
Pedestrian, definition.....	Page 4
Pedestrian-actuated signals:	
Controls.....	240, 271
Detectors (push buttons).....	244,
249, 262	
Midblock crossings, at.....	235
Sign.....	52, 262
Warrants.....	210
Pedestrian barrier, divisional Island.....	349

	Section
Pedestrian Crossing signs-----	51, 90
Pedestrian crossings:	
Pavement markings-----	142-144
Signs-----	51, 90
Traffic-actuated signals-----	240
Pedestrian detectors. (See Pedestrian-actuated signals.)	
Pedestrian interval, traffic signals-----	191, 220, 240
Pedestrian islands (see also Loading islands; Refuge islands)-----	316-344
Definition-----	Page 5, 314
Pedestrian push button. (See Pedestrian-actuated signals.)	
Pedestrian sign—Walk On Left Facing Traffic-----	50
Pedestrian signals-----	166, 210, 269-275
Definition-----	269
Design-----	166, 272
Location-----	274
Meaning of indications-----	167, 273
Operation-----	240, 275
Phases and intervals-----	275
Type of control-----	240, 271
Visibility of traffic signals-----	173
Walk—Wait or Walk—Don't Walk indications-----	272, 273
Warrants-----	270
Pedestrian volume, warranting fixed-time traffic signal-----	206, 207, 210
Performance specifications-----	Page 209
Phases, traffic signals:	
Number-----	190
Rotation of, traffic-actuated signals-----	268
Platforms:	
Loading islands-----	322
Refuge islands-----	336
Playground sign-----	92
Plywood signs, specifications-----	Page 211
Porcelain Enamel Institute-----	Page 211
Porcelain enamel signs, specifications-----	Page 211
Portable signs:	
Fresh Oil (or Tar)-----	83
Men Working-----	82
Mounting of-----	21
School sign-----	87
Turn prohibition signs-----	37
Warning of temporary conditions-----	58
Posts:	
Pedestrian islands-----	324, 326, 339
Signs-----	21
Specification, sign posts-----	Page 212
President's Highway Safety Conference-----	Page 1
Pressure-sensitive detectors-----	245, 261
Pre-timed signals. (See Fixed-time traffic signals.)	
Prima facie speed limit-----	32
Priority of traffic signal installations-----	213
Program timing, fixed-time traffic signals-----	202, 216
Progressive system, fixed-time traffic signals:	
Flexible progressive system-----	226
Simple progressive system-----	225
Traffic actuation at critical points-----	234, 239
Prow:	
Definition-----	Page 5
Pedestrian islands-----	325
Public Roads Administration-----	Page 1
6, 8, 10, 12, 123	
Public utilities, use of Men Working sign-----	2
Push Button For Green Light sign-----	52
Push button, pedestrian-----	240, 244, 249, 262, 271

R

	Section
Railroad grade crossing protection (see also Gates, railroad crossing; Train-approach signals):	
Automatic gates-----	304-311
Coordination with other nearby traffic signals-----	208, 211, 231, 294
Pavement markings-----	142, 146
Signs-----	88, 89
Train-approach signals-----	296-303
Range Cattle sign-----	92
Reassurance Markers-----	95, 98
Records, signal maintenance, value of-----	200
Red:	
Parking prohibition signs, lettering on-----	47, 49
Traffic signals, meaning in-----	167
Red flag, with Men Working signs-----	82
Reflecting coatings (see also Reflector markers; Reflectorization):	
Color-----	15
Specifications-----	Pages 211, 212
Types-----	15
Reflector buttons (see also Reflector markers; Reflectorization):	
Color-----	15
Design-----	15
Specifications-----	Pages 211, 212
Reflector markers (see also Reflecting coatings; Reflector buttons; Reflectorization)-----	155-157
Application-----	155
Delineators-----	155, 157
Design-----	122
Hazard markers-----	152, 155, 156
Islands, use on-----	325, 352
Obstructions, use on-----	152
Pavement-width transitions, use at-----	75, 138
Traffic signs, distinguished from-----	15, 23
Types-----	121
Reflectorization (see also Reflecting coatings; Reflector buttons; Reflector markers):	
Channelizing islands-----	363, 364
Divisional islands-----	351-353
Guide signs-----	13, 15, 94
Loading islands-----	325, 327, 330
Means of reflectorization, signs-----	15
Object markings-----	122, 126
Pavement markings-----	122, 126
Refuge islands-----	342, 344
Regulatory signs-----	13, 15
Signs-----	13, 17
Stop sign-----	29
Warning signs-----	13, 15, 57
Reflectorized signs, position-----	17
Refuge islands-----	331-344
Approach-end treatment-----	340
Definition-----	Page 5
Design-----	335-344
Designation of area-----	336
Dimensions-----	338
End protection-----	339
Functions-----	332
Height-----	338
Illumination-----	342
Legal authority-----	331
Location-----	334
Markings-----	344
Reflectorization-----	342, 344
Side protection-----	341
Signs-----	343
Specifications, summary-----	Page 189
Warrants-----	333
Width-----	338
Regulatory signs-----	25-55
Application-----	25
Classification-----	26
Color-----	8, 27
Definition-----	Page 4
Design-----	27
Function-----	3
Text and symbols, individual signs-----	28, 32, 34-47, 49-55
Research, needed for traffic control devices-----	Page 2

	Section
Residence district, definition.....	Page 4
Restricted roadways, selective exclusion signs.....	44
Retrodirective reflectors.....	15, 122, Page 211
Reverse Curve sign.....	62
Reverse Turn sign.....	61
Reversing traffic flow, lane direction signs.....	287, 289
Road Closed sign.....	53
Roadway, definition.....	Page 3
Rotary islands.....	312
Rough Road sign.....	92
Rounded letters.....	12
Route directions, pavement markings.....	145
Route markers.....	95-112
Application.....	95
Auxiliary route markers.....	95, 97, 99-112
Confirming markers.....	98
Design.....	96, 97
Directional marking assembly.....	95, 104-106
Junction assembly.....	95, 99
Location.....	98, 99, 102, 105
Pavement markings, supplemented by.....	145
Reassurance markers.....	98
Route turn assembly.....	95, 102
Rural area, defined for traffic signal warrants.....	159
Rural district, definition.....	Page 4
Rustproofing, signs.....	Page 210
S	
Safe speed.....	91
Safety zone (see also Loading island; Refuge island), definition.....	Page 5
School crossing, pedestrian signals at.....	270, 271
School Crossing sign.....	90
School sign.....	87
Reflectorization.....	13, 57
Selective exclusion signs.....	44
Semi-traffic-actuated signals (see also Traffic-actuated signals):	
Adjustment of time intervals.....	251, 252, 266
Application and operation.....	237, 239, 240
Controllers.....	250-252, 254
Definition.....	Page 5, 233
Supervisory background cycle.....	239
Shapes, traffic signs.....	7
Shielding of signal faces.....	171
Side protection, pedestrian islands.....	326, 341
Side Road sign.....	65
Sidewalk, definition.....	Page 3
Sight distance, no-passing zones.....	136
Sign(s) (see also individual sign listings):	1-117
Application.....	18
Borders.....	16
Classification.....	3
Erection.....	19
Excessive use of.....	4
Function.....	1
Guide signs.....	93-117
Height.....	17
Illumination.....	13
Islands, use on.....	325, 329, 343, 352, 354, 365
Legal authority.....	2
Location.....	17
Maintenance.....	22
Materials.....	20, Pages 210-212
Messages, other than standard.....	5
Mounting.....	21
Portable.....	21, 37, 58, 82, 83, 87
Position, adjacent to roadway.....	17
Posts.....	21, Page 212
Proximity to each other.....	19
Reflectorization.....	13, 15, 57, 94
Regulatory signs.....	25-55
Specifications, materials and manufacture.....	Pages 209-212

	Section
Sign(s)—Continued	
Traffic signals, signs on.....	38, 167, 172, 230
Warning signs.....	56-92
Signal controllers. (See Controllers.)	
Signal faces (see also Lenses):	
Design.....	165, 166
Height.....	176
Lenses required.....	165
Location.....	175, 178, 179
Number per intersection.....	173
Pointing toward approaching traffic.....	177
Shielding, from traffic not controlled.....	171
Signal heads:	
Mounting, types.....	182
Standards, Institute of Traffic Engineers.....	166
Signal lamps:	
Cleaning and replacement.....	196
Wattage.....	170
Signal observance, relation to signal warrants.....	212
Signals. (See Traffic signals.)	
Signals Ahead sign.....	70, 175
Signals, conflicting indications not permissible.....	193
Signals Set For (25) M. P. H. sign.....	38
Simple progressive system.....	225
Simultaneous system.....	223
Slides sign.....	92
Slippery When Wet sign.....	85
Society of Automotive Engineers.....	Page 211
Soft Shoulders sign.....	84
Sound-sensitive detectors.....	247, 261
"Spacing" signals, to maintain vehicle groupings.....	211
Special pedestrian signals. (See Pedestrian signals.)	
Special traffic signals.....	277-294
Specifications:	
Channelizing islands.....	Page 203
Divisional islands.....	Page 197
Loading islands.....	Page 183
Materials and manufacture.....	Page 209
Messenger wire.....	187
Refuge islands.....	Page 189
Signal cable.....	184, 185
Speed, approach, relation to signal requirements.....	206
Speed control:	
Flexible progressive signal system.....	229
Traffic-actuated signals.....	234, 235, 241, 253, 254
Speed-control signal:	
Definition.....	Page 5
Detector placement.....	260
Interval adjustment.....	266
Types.....	241
Speed limit, night.....	34
Speed limit, prima facie.....	32
Speed Limit sign.....	32, 33
Following Speed Zone Ahead sign.....	85
Speed signs.....	32-36, 91
Advisory speed sign.....	91
End (35) Mile Speed sign.....	33, 36
Night Speed sign.....	34
Speed Limit sign.....	32, 33
Speed Zone Ahead sign.....	35
Speed warrant for fixed-time traffic signal.....	209, 210
Speed Zone Ahead sign.....	35
Splash plates, loading island.....	326
Standard alphabets for highway signs.....	12
Standardization:	
Islands.....	315
Markings.....	120
Signals.....	160, 163
Signs.....	5, 21
State route markers.....	95-97
Priority of U S route markers, position.....	98, 102
Steel, for signs, specifications.....	Page 210

	Section
Stop Ahead sign-----	31, 69
Stop-and-Go signal. (See Traffic signals.)	
Stop, four-way-----	30
Stop line-----	142, 143
Color-----	123
Definition-----	Page 4
Pedestrian signal at midblock crossing, use with-----	274
Stop sign, supplementary to-----	31
Width-----	125, 142
Stop sign-----	28-31
Cross Road sign, when preferable to-----	64
Design-----	29
Directional marking assembly, with-----	19, 105
Flashing red light incorporated in-----	14
Location-----	31
Red flashing beacon as alternative-----	279
Red flashing signal as equivalent-----	167, 279
Stop Ahead sign-----	69
Stop line with-----	143
Traffic signals, as alternative to-----	212
Warrants-----	30
Stop signal (see also Flashing beacon; Flashing signal):	
Definition-----	Page 5
Flashing red, meaning-----	167
Stop, word marking on pavement-----	143, 148
Stopping prohibition signs-----	47, 48
Street, definition-----	Page 3
Street name sign-----	116
Streetcar:	
Clearance lines-----	140
Definition-----	Page 4
Detector, location-----	263
Striping. (See Pavement marking; Center line; Lane line; Object markings; etc.)	
Supervisory background cycle, semi-traffic-actuated signals-----	239
Symbols:	
Advance Turn Marker-----	102
Combination Junction sign-----	101
Curve signs-----	60, 62
Destination Sign arrows-----	113
Detour Marker, special-----	111
Directional Marker-----	104
Double Arrow sign-----	86
Intersection signs-----	64-67
Keep Right sign-----	42
Large Arrow sign-----	68
One Way sign-----	45
Parking signs-----	47
Pavement markings-----	145, 146
Route Marker-----	96, 97
Turn signs-----	59, 61
Winding Road sign-----	63
Word messages, preferred to-----	10
Synchronous controllers, fixed-time signals-----	216
T	
T symbol sign-----	66
Temporary Route Marker-----	107
Detour Marker, as alternative to Road Closed sign, with-----	111
Temporary signs:	
Crossing signs-----	90
Detour Marker-----	111
Fresh Oil (or Tar)-----	83
Men Working-----	82
Reflectorization, unnecessary for daylight use-----	13
Removal of-----	18
Time intervals, traffic signals. (See Intervals.)	
Time-space diagrams, progressive signal systems-----	219
Timing, traffic signals:	
Maintenance of-----	198
Method of assigning Go time, fixed-time signals-----	220

	Section
Timing, traffic signals—Continued	
Traffic requirements, in accordance with-----	219, 220, 266
Track circuits, railroad:	
Railroad crossing gates-----	306, 310
Train-approach signals-----	298
Tractors With Lugs Prohibited sign-----	55
Traffic, definition-----	Page 4
Traffic-actuated control:	
Special merits-----	203, 204
Types-----	236-242
Warrants-----	234, 235
Traffic-actuated controller:	
Limits of adjustment-----	251-257
Types-----	250-258
Traffic-actuated signals-----	201, 203, 204, 233-268
Adjustment and operation-----	264-268
Advantages-----	201, 203, 204
Characteristics-----	201
Coordination-----	239
Definition-----	Page 5, 233
Flashing operation not justified-----	265
Flexible progressive system, use in-----	239
Installation-----	259-263
Interval sequence-----	267
Interval timing-----	266
Operation and adjustment-----	264-268
Phases, rotation of-----	268
Speed control-----	253, 254
Traffic circle. (See Rotary island.)	
Traffic control signal (see also Traffic signal), defined-----	Page 214
Traffic Engineering Handbook-----	219, Page 214
Traffic engineering responsibility-----	Page 3
Traffic islands (see also Channelizing islands; Divisional islands), definition-----	Page 5, 314, 345, 366
Traffic lane:	
Definition-----	Page 4
Lane lines-----	131-133
Width-----	132, 133, 350, 361
Traffic markings (see also Markings) definition-----	Page 4
Traffic paint, specifications-----	Page 213
Traffic sign (see also Signs), definition-----	Page 4
Traffic signals-----	158-311
Auxiliary, where view is obstructed-----	175
Cable, specifications-----	184, Page 214
Cable, underground installation-----	183
Classification-----	162
Cleaning-----	197
Clearance interval. (See Clearance interval.)	
Colors, meaning of-----	167
Coordination, fixed-time signals-----	221-227
Coordination, traffic-actuated signals-----	239
Coordination with railroad crossing signals-----	208, 231
Cost-----	204
Cycle length-----	189
Drawbridges, signal at-----	290-294
Fixed-time vs. traffic-actuated control-----	201-204
Flashing operation-----	30, 188, 208, 210, 232, 265, 279, 280
Four-way stop, preferable alternative to-----	30
Future, provision for-----	181, 184
General features-----	163-200
Improper use of-----	159
Installation-----	175-187, 259-263
Intervals. (See Intervals, traffic signal.)	
Islands, as alternative to-----	212, 358
Lamps-----	170, 196
Legal authority-----	161
Lenses-----	165-171
Maintenance-----	195-200
Meanings of indications-----	167
Mounting-----	182
Overhead location-----	175

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